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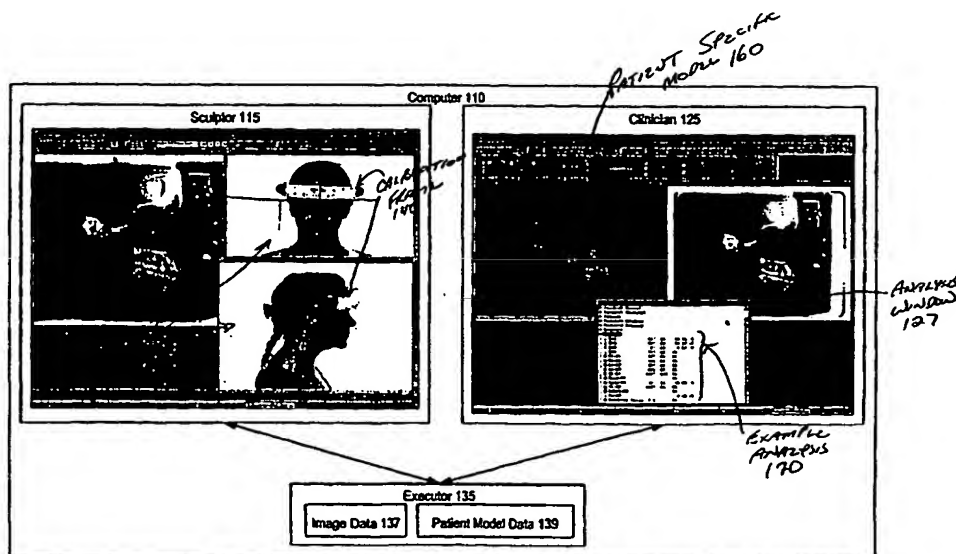
(57) Abstract

A system for relating images and generating a 3D model of anatomy is described. This can be accomplished using three modules. A sculptor module (115) is used to spatially relate images of a patient. The images are generated using a number of different techniques, such as optical and x-ray. The sculptor allows a user to identify the location of different anatomical points in each of the images. Thus, a sculptor allows a user to relate different anatomical points to each other in a 3D space and also relate the points to the images. The clinician module (125) uses the related points to modify or customize a stock model (e.g., a standard anatomical 3D model). The customized model that is created corresponds to a 3D model of the patient's anatomy.

Method and Apparatus for Generating 3D Models from Medical Images

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5 facsimile reproduction by any one of the patent disclosure, as it appears in the Patent and Trademark Office patent files or records, but otherwise reserves all copyright rights whatsoever.

The Field of the Invention

This invention relates to the field of medical imaging. In particular, the

10 invention relates to the generation and use of three-dimensional medical images and models.

Background of the Invention

Efforts to represent images in three-dimensional form go back to the invention of the stereoscope in the 1800's. These attempts continued through

15 the 1950's when 3-D movies (characterized by the red and blue 3-D glasses which served as color filters to separate left and right images) were briefly popular. With the advent of modern computer technology, some companies have engaged in considerable efforts to capture and reproduce three-dimensional information.

20 Typically, three-dimensional information about a scene has been represented using a number of selected points and storing information about each point such as its color, intensity and distance from the camera. For example, a Cyberware

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scanner generates such information by rotating a camera around an object to be modeled and capturing that information at particular points. For a high resolution model, many rotations about the object are required to capture the model information. The vertical displacement of the plane of rotation is

5   decremented by a resolution amount after each rotation. Such models, while accurate, result in a huge number of points at which information must be captured and represented.

Some portions of objects, however, do not require such high resolution. As a result, model builders will frequently manually remove unneeded vertices to

10   simplify the processing required when displaying and manipulating a three-dimensional model.

Such three-dimensional models are typically rendered as wire frames. That is, a plurality of points are identified, corresponding to the points at which image information is captured and the points are displayed together with lines

15   connecting each point with adjacent points. When models are displayed in this manner, they are typically called wireframes because the lines between the points appear to constitute a wire mesh. The individual points in such a wireframe are frequently called vertices because they frequently appear at the vertex of the angles formed by lines going to adjacent points.

20   Software is known for constructing and manipulating three-dimensional models. An example of such software is 3-D Studio Max™ by Autodesk, Inc. Typically, such software packages have the capability to render, or provide a surface texture over the surface of the wireframe model.

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A number of attempts have been made to standardize the representation of three-dimensional information. Of current popularity is the Virtual Reality Mark-up Language (VRML) found with some frequency in an Internet context. Wireframe models are commercially available from a variety of sources.

5   In the medical area, magnetic resonance imaging (MRI), and other imaging technologies, can accurately display two-dimensional slices of a patient. The slices include extremely large amounts of data. Some programs allow doctors to construct 3-D models from these 2-D images. But this process requires a large amount of data processing. The resulting 3-D models are accurate in that they describe exactly what is in the images, but the models do not have any tie to

10 human anatomy. For example, an irregular shape in a 3-D model of a skull may be a tumor, but the system does not relate this additional information to the shape. Even worse, the 3-D model does not even have information indicating that the shape is within a skull. The doctor is responsible for making these

15 determinations. Thus, the 3-D models have limited use. Another problem with many of these systems is that they do not allow the doctor to build the model using combined or a range of imaging technologies (e.g., x-rays, MRIs and photographs). Thus, the models are typically defined using only one imaging technology.

20 A number of problems exist with the existing technology. First, a high degree of technical expertise is required to create and manipulate three-dimensional models. Further, computer processing time is significant and, as a result, special purpose machines, such as those produced by Silicon Graphics, Inc. are commonly used to generate and manipulate three-dimensional models.

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The user interfaces of available commercial software for dealing with three-

dimensional models are highly technical and generally unsuited for use by a

person whose specialty is not in the computer sciences. Also, the 3-D models do

not are not related to medical information about a patient (e.g., a shape in a 3-D

5   model is only a shape, there is no information that the shape is a tumor or body

part). Also, some technologies do not allow doctors to build models from

different types of images (e.g., x-rays, MRI's, and photographs).

Therefore what is desired is an improved 3-D modeling and generation

system.

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Summary of the Invention

The following summarizes various embodiments of the invention.

One aspect of the invention is directed to providing a generic software tool for creating and manipulating three-dimensional models for medical applications.

5   In one embodiment, a number of modules are used to achieve this result. These modules include a Sculptor module, a Clinician module and an Executor module.

The Sculptor module maps all acquired imaging, including those from disparate sources, into a single 3D matrix or database. The images are generated using a number of different techniques, such as optical and x-ray. The Sculptor

10   allows a user to identify the location of different anatomical points in each of the images. Thus, the Sculptor allows a user to relate different anatomical points to each other in a 3-D space and also relate the points to the images.

The Clinician/Consultant module uses the related points to modify or

15   customize a stock model (e.g., a standard anatomical 3-D model). The customized model that is created corresponds to a 3-D model of the patient's anatomy. The model is "smart" in that when certain changes are made to the dot or vertex location of the model, the remainder of the model can be adjusted or morphed to make corresponding changes. Additionally, objects in the model

20   know what part of the anatomy they represent. For example, an object representing the patient's tooth is associated with data indicating that the object is a tooth. This allows for analysis of a patient's anatomy to be performed automatically. The Clinician/Consultant is a database query tool that allows for

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display or visualization of the anatomy and function, manipulation of objects for treatment planning and model analyses.

A third module, called the Executor, is a database that provides overall system file and image management and coordinates the Sculptor module and the

5   Clinician/Consultant modules.

The various features of the invention are illustrated in the context of an application to Orthodontics. In this application, the stock model is a model of the skull and associated facial soft tissues, including the upper and lower jaws. In the examples shown, this model has approximately 300 objects which can be

10   manipulated in the Clinician module to facilitate the kinds of tasks routinely undertaken by an orthodontist.

Some embodiments of the invention include the functionality of some or all of the above modules. For example, in some embodiments, only a subset of the functions performed by the Sculptor are included (e.g., the ability to define

15   related points in multiple images).

Other embodiments of the invention include a method and apparatus for performing medical analysis of the patient's 3-D model.

Although many details have been included in the description and the figures, the invention is defined by the scope of the claims. Only limitations found in

20   those claims apply to the invention.

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Brief Description of the Drawings

The figures illustrate the invention by way of example, and not limitation. Like references indicate similar elements.

Figure 1 illustrates a computer system including one embodiment of the

5   invention.

Figure 2 illustrates an architecture of the software used in one embodiment of the invention.

Figure 3 illustrates capturing images for use in the system.

Figure 4 and Figure 5 illustrates the calibration frame.

10   Figure 6 illustrates an example method calibrating images, generating a patient specific model, and performing analysis from the calibrated images and the patient specific model.

Figure 7 through Figure 24 illustrates user interfaces for a sculpture application.

15   Figure 25 through Figure 40 illustrates user interfaces for a clinician application.

The Description

Definitions

The following definitions will be helpful in understanding the description.

20   Computer – is any computing device (e.g., PC compatible computer, Unix workstation, handheld device etc.). Generally, a computer includes a processor and a memory. A computer can include a network of computers.

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Handheld Device (or Palmtop Computer)- a computer with a smaller form

factor than a desktop computer or a laptop computer. Examples of a handheld

device include the Palm III™ handheld computer and Microsoft's palm sized

computers.

5   User – any end user who would normally wish to retrieve information from

the World Wide Web.

Internet - is a collection of information stored in computers physically

located throughout the world. Much of the information on the Internet is

organized onto electronic pages. Users typically bring one page to their

10   computer screen, discover its contents, and have the option of bringing more

pages of information.

Client - a computer used by the user to make a query.

Server - a computer that supplies information in response to a query, or

performs intermediary tasks between a client and another server.

15   World Wide Web (or Web or web) - is one aspect of the Internet that

supports client and server computers handling multimedia pages. Clients use

software, such as the Netscape Communicator® browser, to view pages. Server

computers use server software to maintain pages for clients to access.

Program – a sequence of instructions that can be executed by a computer. A

20   program can include other programs. A program can include only one

instruction.

Application - is a program.

The detailed descriptions which follow may be presented in terms of program

procedures executed on a computer or network of computers. These procedural

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descriptions and representations are the means used by those skilled in the art to

most effectively convey the substance of their work to others skilled in the art.

A procedure, program or application, is here, and generally, conceived to be

a self-consistent sequence of steps leading to a desired result. These steps are

5   those requiring physical manipulations of physical quantities. Usually, though

not necessarily, these quantities take the form of electrical or magnetic signals

capable of being stored, transferred, combined, compared, and otherwise

manipulated. It proves convenient at times, principally for reasons of common

usage, to refer to these signals as bits, values, elements, symbols, characters,

10   terms, numbers, or the like. It should be noted, however, that all of these and

similar terms are to be associated with the appropriate physical quantities and are

merely convenient labels applied to these quantities.

Further, the manipulations performed are often referred to in terms, such as

adding or comparing, which are commonly associated with mental operations

15   performed by a human operator. No such capability of a human operator is

necessary, or desirable in most cases, in any of the operations described herein

which form part of the present invention; the operations are machine operations.

Useful machines for performing the operation of the present invention include

general purpose digital computers or similar devices.

20   The present invention also relates to apparatus for performing these

operations. This apparatus may be specially constructed for the required

purpose or it may comprise a general purpose computer as selectively activated

or reconfigured by a computer program stored in the computer. The procedures

presented herein are not inherently related to a particular computer or other

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apparatus. Various general purpose machines may be used with programs

written in accordance with the teachings herein, or it may prove more convenient

to construct more specialized apparatus to perform the required method steps.

The required structure for a variety of these machines will appear from the

5   description given.

System

Figure 1 illustrates a computer 110 that can be used to carry out the

invention. The following paragraphs first list the elements of Figure 1, then

describe how they are connected, and then define those elements.

10   Figure 1 includes a computer 110, a sculptor 115, a clinician/consultant 125,

and an executor 135. The sculptor 115 includes a display of a user interface

having a number of patient images 150 that also show a calibration frame 140.

The clinician/consultant 125 includes a similar user interface that includes a a

view of a patient specific model 160 and an analysis window 127. The analysis

15   window 127 includes an example analysis 170. The executor 135 includes image

data 137 and patient model data 139.

This paragraph describes how the elements of Figure 1 are connected. The

sculptor 115 and clinician/consultant 125 communicate with the executor 135.

The sculptor 115 and the clinician/consultant 125 can extract and manipulate

20   information from the image data 137 and the patient model data 139 through the

executor 135.

The following paragraphs describe the elements of Figure 1 in greater detail. How these elements are used to generate a 3D model of a patient's anatomy is describe in relation to Figure 2.

The computer 110 represents a computer system upon which the

5   sculptor 115, the clinician/consultant 125, and the executor 135 can execute. The computer 110 is representative of a standard personal computer such as is available from Dell Computers, Inc. Of course any number of different types of computers could be used as the computer 110. What is important is that the computer 110 some sort of processor and some memory.

10   As an alternative to the system of Figure 1, the sculptor 115 and the executor 135 may run on one computer at one time. While at another time, the clinician/consultant 125 and the executor 135 can run on another computer at another time. Alternatively, all three programs can run on different computers. The computers can be linked together by a network such as the Internet.

15   The sculptor 115 represents a computer program in which a number of different types of patient images 150 can be calibrated using the images of the calibration frame 140. Note that the patient images 150 are from multiple sources. In particular, in this example, an x-ray image and two photographs are shown. The sculptor 115 allows a technician to calibrate the images and identify

20   a number of anatomical locations in the images.

The patient images 150 can be extracted from the image data 137. The image data 137 can be imported from an external source either by transmission over a network or by scanning of x-ray or optical images, for example. Other

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embodiments can include direct capture of x-ray images or other types of media images.

Alternatively, the image data 137 need not be retrieved from the executor 135. The image data may be directly imported into the sculptor 115 and then, later on, possibly be stored in the image data 137.

The calibration frame 140 is an apparatus that includes a number of calibration targets that can be seen in the patient images 150. The calibration frame 140 is worn by the patient during the capturing of the patient images..

The patient model data 139 represents the data generated by the sculptor 115 that can be used to morph the patient specific model 160 and any other information that would be important to patient records. This output of the sculptor 115 can be included the form of two transport files, the (.scl file and .cln file). The executor passes these files to the clinician/consultant.

Turning to the clinician/consultant 125, the data from the sculptor 115 is used by the clinician/consultant 125 to morph a stock anatomy model into a patient specific model 160. The stock anatomy model is 3D model of a standard person's anatomy (e.g., a skull possibly having flesh). The clinician/consultant 125 morphs the stock model into the patient specific model, allows users visualize what a patient's anatomy looks like. Simulations of treatment plans can be shown in the clinician/consultant 125. Also, because the patient specific data 137 defines the relative location of a number of parts of the patient's anatomy, the clinician/consultant 125 can be used to perform various types of analyses on the patient's anatomy. The results of these analyses can be then displayed on the patient images and as well as in the example analysis window 127.

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In the example, which is described throughout, the particular model used will be a stock model of a human skull. The human skull can be used by an orthodontist in planning for, and carrying out, a treatment plan for a particular patient. In this example, the model will have a number of objects including

5   objects corresponding to each of the patient's teeth, the jaw, and other elements of the skull. Importantly, each of these objects can be manipulated individually in the clinician/consultant 125.

An example of a stock model that may be used is one from Viewpoint Data Labs which is specifically created for orthodontic applications. A full custom

10   stock model can also be used. The stock model represents the average structure of a piece of anatomy. The Executor (database) will compile normative stock models to match patient demographics of age, race, sex and body type. The stock model has a coordinate system where each point is referenced to another point within itself. The information retrieved in the sculptor 115 allows that

15   stock model to be morphed according to the dimensions and measurements from the sculptor 115. Examples of the individual objects available in the generic stock model, and the resulting patient specific model 160, include individual teeth, the jaw, and the skull. Each of these objects has a separate coordinate system which is referenced to the coordinate system in the patient specific

20   model 160. In this way, when a particular object is selected, one may manipulate that object and change its relationship to the global reference system of the patient specific model 160.

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Other aspects of the invention are some of the new user interfaces features

presented in the sculptor 115 and/or the clinician/consultant 125. These new

user interface features will be described in greater detail below.

Figure 2 illustrates the various responsibilities of each of the three programs

5   of Figure 1.

The sculptor 115 is responsible for input/output control of the patient

images 150. The sculptor 115 allows for a calibration between the various

images. 3D measurements of various locations defined in the calibration process

can then be determined. The sculptor 115 includes a graphical user interface for

10   performing the various features of the sculptor 115. The viewer supports the

viewing of 3D models (useful where a piece of anatomy needs a more detailed

identification).

The model matching allows a user to match portions of the stock model to

points on one or more patient images 150. In addition, model matching includes

15   the ability to spatially match or register two models of the same patient at

different points in time. Thus, areas of a model that are not already predefined in

the sculptor 115 can be defined. These new locations can then be used for more

accurate morphing process of the particular part of the anatomy of interest, will

facilitate a morphological comparison of two patient specific models and will

20   facilitate the comparison of patient specific models to normative data. For

example, is one part of a patient's anatomy requires specialized treatment, a more

detailed patient specific model 160 may be desired. In such a case, the sculptor

115 allows the user to identify the location of previously undefined points of the

stock model in the patient images 150.

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The executor 135 takes responsibility for the database storage and transferring of the image data 137 and the patient model data 139. The executor 135 includes Internet access for communicating with one or more sculptors 115 and one or more clinician/consultants 125. The executor 135 also

5 has encryption capabilities to protect the security of the information stored by the executor 135.

The clinician/consultant 125 includes the following functions. Diagnosis, treatment planning, predictions, analyses, and metrics, are all examples of the type of functions that can be performed on the patient specific model 160 and

10 patient model data 139. Examples of these areas are described in greater detail below. The clinician/consultant 125 also keeps track of the stock objects, or stock models, that may be used in the morphing processes.

The clinician/consultant 125 includes a graphical user interface and viewer for viewing patient information, the 3D model, analysis, etc.

15 The morph editor is used to modify any morphing that is done to generate the patient specific model 160.

The simulator simulates the motion of objects within the patient specific model 160. The simulator could also be used to simulate the predicted motion of objects in the patient specific model 160. Thus, the simulator can be used to

20 simulate the movement of a jaw, or treatments such as the straightening of teeth.

<u>Image Capture Example</u>

Figure 3 illustrates example relationships between a patient, a camera and other imaging technologies, for the purpose of capturing images. The capture images can then be imported into the sculptor 115.

5   A patient 300, a camera 310 and an x-ray device 320 are shown in Figure 3. The camera 310 and the x-ray device 320 can be used to capture the image data 137. These captured images can be all from one camera, x-ray machine, or the like. However, some of the more important features of the invention can be realized when mixed modes of image capturing are combined. In this example,

10   two devices, the camera 310 and the x-ray machine 320, are used to capture image data about the patient 300 from multiple vantage points. Other example modes of image capture include MRIs, ultrasound imaging, infrared imaging, and the like. The camera 310 and x-ray 320 are merely symbolic of the fact that images of the patient are captured using various types of imaging technology.

15   In the orthodontic application, it is desirable to have both x-ray (both skeletal and soft tissue) and optical modes for capturing images of the patient 300. Although the camera 310 and x-ray device 320 are shown in the plain of Figure 3, this is not necessary, and in fact, may not be desirable. In the example of an orthodontic application, the preferred x-ray images would include a frontal

20   image, a lateral image, and a frontal image with the head tipped back. The preferred photographic images may include a frontal image and two lateral images.

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Example Calibration Frame

Figure 4 illustrates a front view and a side view of a calibration frame 140 that may be used in some embodiments of the invention. Images of this calibration frame 140 appears in the patient images 150. The images of the

5 calibration frame 140 can then be used in the sculptor 115 to calibrate the various images.

The calibration process includes recording the anatomy with the calibration frame in place using any number of imaging modalities. The 3D location of the calibration markers and an associated co-ordinate system is included as a priori

10 knowledge within the sculptor. Through calibration of each imported image, the sculptor computes the location of the imaging sources as a point source with seven degrees of freedom (DOF). Seven DOF includes the x, y, z, yaw, pitch, roll and focal length of the imaging source. The calibration process maps the associated images into the 3D matrix associated with the calibration frame. Two

15 or more calibrated images, through a process of triangulation, can be used to determine the 3D location of any associated points on the image sets.

The calibration frame 140 can include a top strap 405, a strap 410, an adjustment knob 420, and a plexi-glass frame 430. The top strap 405, the strap 410, and the adjustment knob 420, work together to keep the calibration frame

20 in a substantially fixed position on the patient 300. Thus, when the images of the patient are capture, from the various modes, a common reference frame is established.

The following describes the calibration frame 140 in greater detail. The strap 410 is designed to encircle the patient's 300 head. The top strap 405 is designed

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to prevent the strap 400 assembly from dropping too far down on the patient's head.

In some embodiments, the top strap 405 and the strap 410 are part of headgear normally associated with a welding visor from which the face shield has

5   been removed.

One of the problems with the welding headgear, by itself, is that it flexes in ways that are undesirable for image capture. This prevents a good common reference frame from being established. Accordingly, a rigid plexi-glass frame 430 is used to mount a number of calibration targets 440. The circumference of

10   the strap 410 is adjusted using a ratchet and a knob 420. They can be used to adjust the amount of overlap between the ends of the strap 410.

The calibration targets 440 provide measurement references during the calibration of the various patient images 150. The calibration targets 440 include a number of spherical shapes, possibly having substantial x-ray attenuation

15   properties. However this is not a requirement, and may not be desirable depending on the imaging technology that is being used to capture the patient images 150. Alternative embodiments can include different materials such as cod liver oil capsules as calibration targets 440. Alternative embodiments can also include different shapes of calibration targets 440, such as crosses. Although

20   BBs, such as shot gun pellets, could be used, it is preferred to use bearings because their spherical shape is held to a closer tolerance. A characteristic of the calibration targets 440 is that they are visible in both optical and x-ray images. However, what is important with respect to the calibration targets 440 is that

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they provide a fixed reference frame by which patient images 150 can be

calibrated. Thus, they should be viewable in each of the patient images 150.

Importantly some of the calibration targets 440 can be of different types of

materials such that some of the calibration targets 440 appear in some of the

5   images while others of the calibration targets appear in others of the images. As

long as enough of the calibration targets 440 are visible in enough of the images,

calibration can be performed.

Additionally, a single calibration target could be made of different materials.

For example, a cod liver calibration target could be positioned very close to a

10   crosshair. The crosshair would indicate the position of the calibration target in

the photographs, while the code liver oil capsule would indicate the position of

the calibration target in MRI images.

Generally the calibration targets 440 are positioned in the calibration

frame 140 such that it is unlikely that in any one image the calibration targets will

15   overlap to any great extent. It is also preferable, that at least four of the

calibration targets are visible from each image perspective. Thus the shape of

the calibration frame for holding the calibration targets 440 may vary from

medical application to medical application. Thus multiple different calibration

frames can be supported in the sculptor 115. Importantly, when the images have

20   been captured, a session folder is created in which to store the images from the

session, and the patient data are stored in a patient folder of the file management

system operated under control of the executor 135. The type of calibration

frame used 140 can also be stored with that information.

The attachment 450 (also referred to as an appliance) represents another way in which calibration targets can be included in images of the patient 300. For example, where a particular image is restricted to a small area of the patient's head, the calibration attachment 450 can be still used to calibrate. For example,

5   where an x-ray image is collimated to only focus on a smaller portion of the patient's face, the calibration targets 440 in the attachment 450 would still appear in that x-ray image.

Figure 5 illustrates another embodiment of the calibration frame 140. In this example, the plexi-glass frame 430 has a number of bends instead of the

10   continuous curve shown in Figure 4. This facilities the attachment of calibration attachments 450 to the calibration frame 140.

Figure 5 illustrates a top view 502, a front view 504 and a cross section view 506 of the calibration frame 140. The front view 504 and the cross section view 506 illustrate how attachment sites 530 can be included on the calibration

15   frame 140. (Note, the top view 502 does not illustrate the attachment sites 530, but the sites may be viewable from the top view 502.)

The cross sectional view 506 illustrates how an attachment can be attached to an attachment site 530 using a captive neural thumb screw 550. The attachment 450 can be stabilized using dowel pins 560. This example illustrates

20   an acrylic appliance (attachment 450).

Importantly, Figure 5 illustrates an acrylic appliance support that can be used a part of the calibration frame 140. This is merely illustrative of how appliances or attachments 450 could be attached to the calibration frame 140. What is

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important is that there is some way to include calibration targets 440 in different

images that may not include the the calibration frame 140.

Example Method of Creating and Using Patient Specific Data

Figure 6 illustrates one embodiment of the invention where the programs of

5   Figure 1 are executed on one or more computers 110. In this example, the

patient images 150 are calibrated to generate the patient specific model 160.

This information is also used to perform a number of analyses on the patient

model and related data. Figure 6 can be broken down into three general

processes: a capturing of the patient specific data 602, generating the patient

10   model 604, and performing analyses and related work on the patient model and

related data 606.

Starting with the capturing of the patient specific data 602, at block 610, the

calibration frame 140 is mounted on the patient 300 head. This can be done by a

technician at a medical facility. The top strap 405, the strap 410 and the

15   adjustment knob 420 can be use to snuggly fit the calibration frame 140 to the

patient's 300 head.

Next, at block 620, a number of different images of the patient are captured.

Importantly, the calibration frame 140 and/or the attachments 450 are included in

these images.

20   Next, at block 630, the sculptor 115 is used to import all the image data 137.

This image data 137 is now calibrated using the image information of the

calibration frame 140. In particular, each patient image 150 is associated with a

calibration frame template (a computer representation of the calibration frame

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140). A user will match a calibration frame template up with the image of the calibration frame 140 in each of the patient images 150. This tells the computer 110 how the calibration frame 140 is oriented and positioned in the image. Thus, all the points within the image can now be associated with, or
5 referenced to, the calibration frame 140.

As noted above, the calibration process involves calibrating locations relative to the position of the calibration frame 140. As part of this process, it is convenient to define a coordinate system for a particular patient. This coordinate system can then be mapped into the various views for patient
10 images 150. For example, a first plane may be defined that is parallel to approximately the patient's pupils. A y-plane can then be defined through the mid-sagittal plane of the patient. The last center plane can be determined from the cross product of the other two planes.

Next, at block 640, a number of anatomic locations in each of the images are
15 identified. Examples of this process are described below. What is important, however, is that a set of all the anatomic locations in the patient images 150 is defined. Appendix A includes a list of those locations.

An example of identifying anatomic location 640 would include such things as identifying the locations of the ears, a trace of the jaw, the various points on
20 specific teeth.

The set of anatomic locations that need to be defined is dependent upon what stock model is to be used and how well the resulting morphed patient specific model 160 should match with the patient's exact anatomy. For example, if only a

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portion of a skull is to be modeled, only those anatomical locations associated

with that portion of the skull need be identified.

Different medical applications may have different specific features of interest

that are identified in the identification of anatomic locations. Orthodontists, for

5   example, tend to concentrate on landmarks in the skull. These landmarks tend to

be points concentrated on the mid-sagittal plane, teeth, and jaw. The ability to

identify these landmarks and cross correlate them in the various patient

images 150 is an important feature for specific medical applications. However,

the specific features and anatomic locations that are important to a particular

10   discipline will vary from application to application. Once the calibration frame

has been used to calibrate the various patient images 150, however, all images

and anatomic locations can then be referenced to that calibration frame. This

information can then be stored in the transport file (.scl file).

The following describes an example way of identifying a landmark in more

15   than one image. It is important to identify the landmark location in multiple

views to completely determine the 3D co-ordinates (x, y, z) of that landmark.

To do this, the user can perform the following steps using the computer 110.

First, the user selects a point to be identified. Next, the user then places that

point in one of the images. The sculptor 115 then generates a line through that

20   point in each of the other images. The line (epi-polar line) originates from the

imaging source and is projected through a landmark point of image A and onto

all other images mapped into the 3D matrix. The display length of the line

projected onto the other images through the point of interest is arbitrary but the

length of the line can be constrained by a priori knowledge of geographic region

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of the point of interest associated with each image. The projection of that line is displayed in each of the other images as noted. The display in the other images will appear different because the projection of that line, in 3D space, will be viewed from different perspectives in each of the images. The user now can use

5   the projected line to identify the corresponding landmark location in the other images. By looking along the projected line in each of the images, one can quickly identify where the landmark should be located in that image. Once the point has been defined in two of the images, the point may be automatically defined in all of the other images.

10   Rather than identifying individual points however, it is sometimes desirable to outline, or trace, certain anatomic features. The tracing can be done by specifying one or more connected points in a number of the patient images 150. An example of this would be tracing the outline of an eye socket in an x-ray image. This would be important for certain medical applications relating to the

15   eye. This traced information could then be stored with the landmark location information.

By using the calibration frame 140 and the relationship between the various images, an accuracy of 0.1 mm can be achieved with respect to the location of landmarks and the tracing of anatomic parts.

20   Thus the capture of the patient specific data process 602 has been completed. Next, the patient specific model 160 is generated in the generate patient model 604 process.

Once all the anatomic locations are identified in the sculptor 115, the data for that patient can be exported to the executor 135. This information can then be

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loaded into the clinician/consultant 125. The clinician/consultant 125 includes a

stock model which is to be morphed against the information drawn from the

sculptor 115 for a particular patient. In this example, the anatomic locations

identified in the sculptor 115 from the patient images 150 are all associated with

5   the calibration frame 140. Thus, exact measurements relative to each other of

anatomic locations have been identified. Thus relative location information is

then used to morph the stock model into the patient specific model 160. This

can be done using standard techniques for morphing data. The resulting patient

specific model 160 includes all the object information in the original stock model

10   but has been customized with the measurements of a specific patient.

Importantly, this allows significant types of manipulations to be performed that

have not previously been performed in medical imaging systems. Examples of

these processes are now described.

The following describes an example analysis that is performed using the

15   patient specific model 160 and the other patient data. In this example, a patient

model is displayed. An example of this is shown in the picture of the

clinician/consultant 125 on the left hand side of the display area in Figure 1. In

this example, the model is shown as a number of dots in space.

Within the clinician/consultant 125, the user can select an analysis type from

20   the analysis window 127. The analysis can be derived from either the landmarks

that have been previously identified in the sculptor 115, from the morphed three

dimensional model data in the patient specific model 160, or from measurements

taken by the user from within the clinician/consultant 125. An example of the

analysis performed is shown in the example analysis 170. This conforms to

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block 670 of Figure 6. The example analysis 170 illustrates example output from

an analysis procedure. In the case of orthodontics, measurements may be taken

to perform any number of standard orthodontic analyses such as a Ricketts

analysis or a McGrann analysis. Other types of analysis, treatments, etc. are

5   described in the following sections.

As part of the analysis, a user can use the clinician/consultant 125 to rotate

and manipulate the patient specific model 160. The patient's face can be mapped

onto the generic model from the photographs in the patient images 150.

Other types of analysis, or evaluations, performed in the clinician/consultant

10   125 are now described.

For a particular tooth, which is a separate object, one may wish to select that

tooth and move it somewhat out of its socket. This could be used for example in

showing a patient what their teeth would look like if they were straightened.

Alternatively, the axis of the tooth for a particular patient may be rotated from its

15   present location to an ideal location. Using the model, by selecting the tooth,

one could not only translate the tooth, but rotate it to show it in a different

orientation with respect to the other elements in the patient specific model 160.

In some embodiments of the invention, the viewing and manipulation of

individual objects of the patient specific model 160 is done using the VRX

20   viewer, commercially available from Synthonics Technologies, Inc.

The user is able to hide objects in the patient specific model 160. This,

would correspond, in the case of a tooth, to extracting a tooth, leaving more

room for reorienting other teeth in the jaw.

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In the case of an orthodontics application, there are certain standard viewpoints used by orthodontists. These include an interior view, a superior view, a lateral view, a frontal view, intra-oral view, and/or an extra-oral view. Once adjustments have been made to the generic stock model, to reflect the

5   patient specific features, i.e., the generation of the patient specific model 160, a treatment plan can be applied. The patient specific model 160 can be rendered by placing a skin over the model to show the external appearance after the modifications have occurred. An example of such a system that would allow this is QuickLook trademark rendering product from Synthonics Technologies, Inc.

10   This permits photorealistic texturing of the model, so the patient can see their actual face after the orthodontic work has been completed.

When using this invention for various medical applications, one can use the capabilities of the software and the models to display and communicate to patients what will be occurring with respect to their treatment. Patients can

15   visualize the changes that will occur in their mouth as a result of some orthodontic treatment.

Further, by using the techniques described herein to generate the three dimensional model, one achieves such a model with a much lower dosage of radiation than would be required, for example, if such a model were constructed

20   by a CAT (Computer Assisted Tomography) scan.

Further, by constructing a transport file that contains only limited patient specific information, a user need only identify, for example, two hundred landmarks in an orthodontic application, versus hundreds of thousands or so vertices that would be required for completely defining the patient specific

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model 160 by itself. As a result, the full patient specific information can be

transmitted through a relatively low bandwidth network in a relatively small

amount of time. Such information could be transported over the Internet to

insurance companies, patients, and specialists. This is significantly different than

5   what is required to transfer full three dimensional models over a network. Thus,

measurement data could be taken in the sculptor 115 and sent to a dental lab

across the network very quickly and efficiently. Alternatively, information about

the patient specific model 160 can be transmitted across the network with the

same minimal bandwidth requirements to a dental lab, where a finished bridge

10   could be produced in accordance with the specification and measurements

contained in the patient specific file.

Automated Calibration Target Identification

The following describes an example system for automatically identifying the

calibration targets 440. In this example, BBs will be used as calibration targets,

15   however, the general process can be used for most any type of calibration target.

The image of each BB is circular in the patient images 150. This is why the

spherical shape was chosen, so it's image would be circular, regardless of the

viewing angle. For a given camera geometry, one would expect the blob formed

by the image of a BB in the film to have a certain size. Specifically, one would

20   expect a BB to appear with a diameter of a certain number of pixels for a

particular camera geometry. One can select the correlation patch corresponding

substantially to that expected size and shape and then search over the patient

image space looking for correlations between the portion of an image underlying

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the correlation patch with the corresponding pixels for the expected blob pixel

set. The points with the highest correlation are likely the locations of the BB.

When this has been done for each BB in a particular set of patient images 150,

one can identify the centroid of the region in three dimensional space formed by

5   the intersection of the projections of a BB image from different patient images.

The centroid location in 3D space is then determined as the center of the BB

relative to the calibration frame 140. This information can then be stored and

associated with that particular image.

The above process describes a fully automated calibration target

10   identification technique. However, in other embodiments of the invention, the

user can drag and drop calibration target identifiers near a calibration target, and

the computer 110 (the sculptor 115) can look for a calibration target near where

the user dropped the calibration target identifier.

Sculptor Interface Examples

15   Figure 7 illustrates the sculptor 115 application interface. This is shown as

sculptor interface 715. Sculptor interface 715 includes a sculptor toolbar 720 for

performing various functions in the sculptor 115. In this example figure, a

patient image 750 is being displayed. Patient image includes a view of the

patient 300 and view of the calibration frame 140.

20   Figure 8 illustrates the placement of an unaligned calibration template 810 in

the patient image area. The unaligned calibration template 810 will be aligned

over the next few figures to show how the sculptor 115 can be used to determine

a calibration reference frame for a patient image.

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Figure 9 shows that a number of calibration target selectors 910 have been placed over the calibration targets 440 in the patient image 750. The calibration target selector 910 is dragged and dropped onto a calibration target in the image of the calibration frame 140.

5   Figure 10 illustrates the partially aligned calibration template 110. The partially aligned calibration template 1010 has been aligned using the calibration target selectors 910.

Figure 11 illustrates the aligned calibration template 1110. The aligned calibration template 1110 now provides the sculptor 1115 with a reference frame

10   for the patient image 750.

Figure 12 illustrates the sculptor interface 715 having a second patient image 1250 being displayed. The calibration frame 140 can be seen in both of the images. Additionally, the aligned calibration template 1110 can be seen. A similar alignment process was performed to align the calibration template in the

15   patient image 1250.

Figure 13 illustrates the placement of a coordinate reference origin 1310 to define a reference plane for use by the user. The reference planes help in the identification of anatomic locations.

Figure 14 illustrates creating a trace using the sculptor 1115. In this

20   example, a trace name 1410 is displayed in the sculptor toolbar 720. In this example, the trace name 1410 is the mid-line soft tissue trace. A user has traced his midline soft tissue trace 1410 in at least two of the patient images 150. The midline soft tissue trace 1410 is also shown in the patient image 1450. This may be the preferred image to trace the mid-line soft tissue trace 1410. The reason

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for this is that the profile of the patient's soft tissue is most easily seen in this

image. The midline soft tissue trace 1410 can also be defined in the patient

image 750. The sculptor 115 then propagates this trace to the patient image

1250.

5   Figure 15 illustrates a user interface enhancement in the sculptor 115. In

particular the sculptor 115 allows the user to perform a localized histogram

normalization in a patient image. For example, localized enhancement 1510 is

performed in the patient image 1250. This allows the user to enhance portions

of the various images.

10   Figure 16 illustrates a trace and landmark view 1620 where the patient image

1250 is removed from the display. This further allows the user to determine

where traces and landmarks are being positioned. In particular the example

traced 1610 is shown. By removing the patient image 1250, the example trace

1610 can be more easily seen.

15   Figure 17 illustrates a rotated view 1720 of the example trace 1610. The

user can rotate the traces, or otherwise manipulate the traces. In one

embodiment of the invention, the viewer tool used in the clinician/consultant 125

is also used for rotating and displaying the traces.

        Figure 18 illustrates a number of landmarks and traces being displayed in

20   multiple images. In particular landmarks and traces can be seen in the patient

image 1450, the patient image 750, the patient image 1850, and the patient

image 1250. This allows for some basic measurement and analysis features of

the sculptor 115 to be used.

Figure 19 illustrates a measure between a bone and a soft tissue point. In this example, the distance measured is the distance from the post nasal spine landmark to the midline soft tissue trace. The measurement line 1910 illustrates where the measurement is taking place. The measurement information 1920

5   shows how many millimeters long the measurement line 1910 is. This calculation can be made because the patient image 1250 has been calibrated with the calibration template 140.

Figure 20 illustrates how epi-polar lines 2020 can be used in the placement and location of landmarks and traces. In this particular example, a post nasal

10   spine landmark is being shown using epi-polar lines 2020. The post nasal spine landmark 2010 was first placed in the patient image 1250. This caused epi-polar lines to be shown in the other two images. Next the post nasal spine landmark 2010 was identified on one of the epi-polar lines in the patient image 1850. This automatically placed the post nasal spine landmark marker 2010 into the last

15   patient image 2050.

Figure 21-24 illustrates the creation of a trace. In Figure 21, a right mandible trace 2110 is shown. This trace was performed by a sequence of click and drag actions. The right mandible trace 2110 includes a number of trace points, such as a trace point 2120. These trace points are connected in the line

20   to form the trace. Now the user will make the same trace in a different patient image.

In Figure 22, a portion of the right mandible trace 2110 is being created in the patient image 1850. The trace line 2200 corresponds to the right mandible trace 2110. The trace line 2200 has, or will have, the same number of points as

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the right mandible trace 2110. The sculptor 115 ensures this. When the user

places a trace point down such as the trace point 2210, the trace line 2200

extends from that point and shows where the next trace point 2220 would be

placed along the trace line 2200. The user can then manipulate the location of

5   this next trace point 2200 by dragging the trace line 2200 into the appropriate

location. When the user has placed the next trace point 2200 in the appropriate

location, the user can then select using a mouse click to position the next trace

point 2200 permanently. Then another trace point is displayed until all of the

trace points in the right mandible trace 2110 have been placed. This provides a

10   particularly simple method of propagating a trace from one patient image to the

next patient image.

Figure 23 illustrates the placement of the trace point 2220 after the user has

clicked on the mouse. Once the right mandible trace 2110 has been completely

laid down (2D trace) in the patient image 1850, the epi-polar lines of points on

15   the right mandible trace can be projected onto any other calibrated patient image.

These epi-polar lines constrain the identification of the corresponding landmark

to those lines. Once the correspondence has been completed and the 3D co-

ordinates of the points on the trace have been computed (triangulated) then the

right mandible trace 2110 can automatically be propagated to another calibrated

20   patient image. Thus by defining the right mandible trace 2110 in two images, the

right mandible trace 2110 has been completely defined in the space

corresponding to the calibration frame 140. Therefore wherever the calibration

frame 140 is identified, the corresponding location of the right mandible trace

2110 can be determined by the sculptor 115.

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Clinician/Consultant Interface Examples

Figure 25 through Figure 40 illustrate various user interface features of the clinician/consultant 125. These figures illustrates how a user can access the patient specific model data, create and manipulate the patient specific model 160, and perform analysis, treatment and the like on the model and the model data.

Figure 25 illustrates an .SCL file load window 2510 that can be use to load a .SCL file. In this example, the .SCL file is the patient specific file 2520 that was generated in Figure 7 through 24.

Figure 26 illustrates the morphing interface 2600 that can be part of the clinician/consultant 125. Here the patient image 750 is shown with a partially morphed stock model 2610. After the morphing is complete, the patient specific model 160 is created. The morphing interface 2600 need not be used by the medical practitioner, but it does help illustrate the morphing process.

Figure 27 illustrates a morphed and texture mapped patient specific model view 2710. Here the patient specific model view has been rotated. Note that the photo image texture mapped onto the model is the patient image 750.

Figure 28 illustrates a wireframe view 2810 of the patient specific model 160. The morphing interface 2600 allows the user to rotate the view of the patient specific model 160 and to change the way in which the model is displayed.

Figure 29 illustrates a dot contour view 2910 of the patient specific model 160. The dot contour view 2910 shows the points that are used to define the patient specific model 160. During the morphing process, the points in the stock model are repositioned, according to the patient model data, to create the patient specific model 160.

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Figure 30 illustrates the clinician interface 3010. The clinician interface 3010

is the interface that would normally be used by the medical practitioner when

performing analysis, developing a treatment, or presenting information to the

patient. In this example, the clinician interface 3010 includes a patient specific

5   model flesh view 3010.

Figure 31 illustrates the patient specific model skull view 160 having a

number of landmarks and control points showing.

Figure 32 illustrates an example analysis that has been performed. Here a

Steiner analysis has been performed on some of the anatomical locations

10   identified in the sculptor 115. The analysis window 127 shows the results of the

analysis. The patient image 1250 and the dot view of the patient specific model

3210 show the analysis lines 3230. Normally, the medical practitioner would

have had to draw these lines on the x-ray image, and then measure those lines.

With the clinician/consultant 125, these processes are automated.

15   Figure 33 illustrates a partially planned treatment where an arch form

template 3320 has been put into the jaw object dot display 3310. Importantly,

the jaw object can be selected and manipulated separately from the rest of the

patient specific model 160. Additionally, the medical practitioner can place an

arch form template 3320 and perform simulations of how the teeth may will be

20   affected by a particular treatment. Note that the user interface now includes a

tool for defining the wire, pivot points, and alignment.

Figure 34 illustrates a jaw object solid display 3410 where a particular tooth

has been selected (shown as tooth selected display 3420). Figure 35 illustrates a

similar view, except the jaw object dot display 3510 is shown instead.

Figure 36 illustrates the where the user has partially extracted and tilted the tooth. This could be used to show a patient what an extraction would look like. Figure 37 illustrate the top view of this configuration.

Figure 38 illustrates the jaw object solid display 3410 where the tooth has
5   been extracted.

Figure 39 illustrates another feature of the clinician/consultant 125 user interface where slice planes have been placed through the jaw object. The jaw object display 3920 is used for positioning the slice planes (e.g., slice plane 3910). The jaw object display 3930 shows the results of the slice plane 3910.
10   The clinician/consultant 125 user interface allows the user to position and control multiple slice planes through the object.

Figure 40 illustrates a partially transparent slice plane 4010 and a partially transparent slice plane 4020 positioned though the jaw object display 3920. The jaw object display with transparent slices 4030 shows the result of the slice
15   planes.

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Appendix A

The following table shows the landmarks and traces used in the creation of

the patient specific model 160. Other embodiments of the invention can use

other landmarks and/or traces. The following list has been chosen as they

represent commonly referred to anatomic landmarks.

```
// ===== landmarks ====
  abbr          Description
// ====================
LB_ME           Menton
LB_GN           Gnathion
LB_PG           Pogonion
LB_B            B Point
LB_ID           Infradentale
LB_LIE          Lower Incisor Incisal Edge
LB_ADP          Anterior Downs Point
LB_UIE          Upper Incisor Incisal Edge
LB_UIL          Labial of the Upper Incisor
LB_SD           Supradentale
LB_A            A Point
LB_ANS          Anterior Nasal Spine
LB_UIA          Upper Incisor Apex
LB_UIB          Upper incisor Lingual Bony Contact Point
LB_LIB          Lower incisor Lingual Bony Contact Point
LB_LIA          Lower incisor Apex
LB_SYM          Lingual Symphyseal Point
LB_PMC          Premolar Mesial Contact point
LB_PDC          Premolar Distal Contact point
LB_LMR          Lower Molar Root Apex
LB_LMJ          Lower Molar Mesial CEJ
LB_LMC          Lower Mesial Contact
LB_UMT          Upper Mesial Cusp Tip
LB_PDP          Posterior Downs point
LB_LMIT         Lower molar Mesial Cusp Tip
LB_UMJ          Upper molar Mesial CEJ
LB_UMR          Upper molar Root Apex
LB_UDT          Upper molar Distal Cusp Tip
LB_FPP          Functional Occlusal Plane Point
LB_LAB          L Ant Border Ramus
LB_RAB          R Ant Border Ramus
LB_LGO          L Gonion
LB_RGO          R Gonion
LB_GOI          Gonial Intersetction
LB_LPB          L Post Border Ramus
LB_RPB          R Post Border Ramus
LB_PSE          Posterior Skull External
LB_PSI          Posterior skull   internal
LB_OCP          Occipital Protuberance
LB_I            Inion
LB_OP           Opisthion
LB_BP           Bolton point
LB_BA           Basion
LB_AR           Articulare     Posterior
LB_AA           Articulare     Anterior
LB_CO           Condylion
LB_LCO          L Condylion
LB_RCO          R Condylion
LB_PO           Porion
LB_LAPO         L Anatomic Porion
```

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LB_RAPO	R Anatomic Porion
LB_S	Sella Turcica
LB_SE	Ethmoid Registration Point
LB_GBI	Glabella internal
LB_GB	Glabella
LB_FSS	Frontal Sinus Superior
LB_LSUP	L Supraorbitale
LB_RSUP	R Supraorbitale
LB_FSI	Frontal Sinus Inferior
LB_FMN	Frontomaxillary nasal suture
LB_N	Nasion
LB_NB	Nasal Bone
LB_LLO	L Lateral Orbit
LB_RLO	R Lateral Orbit
LB_LOR	L Orbitale
LB_ROR	R Orbitale
LB_IZ	Inferior Zygoma
LB_PNS	Post Nasal Spine
LB_PTMI	Pterygomaxillary Fissure Inferior
LB_PTMS	Pterygomaxillary Fissure Superior
LB_LCP	L Coronoid
LB_RCP	R Coronoid
LB_3VS	3rd Vertebra Superior
LB_3VA	3rd Vertebra Anterior
LB_3VI	3rd Vertebra Inferior
LB_3VP	3rd Vertebra Posterior
LB_3VC	3rd Vertebra Canal
LB_3VSP	3rd Vertebra Spine
LB_4VS	4th Vertebra Superior
LB_4VA	4th Vertebra Anterior
LB_4VI	4th Vertebra Inferior
LB_4VP	4th Vertebra Posterior
LB_4VC	4th Vertebra Canal
LB_4VSP	4th Vertebra Spine
LB_COL	Columella
LB_LA	L Articulare
LB_RA	R Articulare
LB_LM	L Mastoid
LB_RM	R Mastoid
LB_LAGO	L Antegonion
LB_RAGO	R Antegonion
LB_LR1	L R1
LB_RR1	R R1
LB_LR2	L R2
LB_RR2	R R2
LB_LR3	L R3
LB_RR3	R R3
LS_GL'	Soft Tissue Glabella
LS_Na'	Soft Tissue Nasion
LS_No'	Nose Tip
LS_Sn'	Subnasale
LS_A'	Soft Tissue A Point
LS_UL'	Upper Lip
LS_LL'	Lower Lip
LS_B'	Soft Tissue B Point
LS_Pog'	Soft Tissue Pogonion
LS_Gn'	Soft Tissue Gnathion
LS_Me'	Soft Tissue Menton
LS_URh'	Upper Rhinion
LS_LRh'	Lower Rhinion
LS_UEm'	Upper Embrasure
LS_LEm'	Lower Embrasure
LS_LEyM'	L Eye Medial
LS_LEyL'	L Eye Lateral
LS_REyM'	R Eye Medial
LS_REyL'	R Eye Lateral
LS_LLc'	L Corner Lip
LS_RLc'	R Corner Lip
LS_LNp'	L Posterior Nares

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```
LS_RNp'         R Posterior Nares
LS_LN1C'        L Nasolabial Crease
LS_RN1C'        R Nasolabial Crease
LS_LTr'         L Tragus
LS_RTr'         R Tragus
LS_TH'          Top of Head

// ==============Teeth===================================
NOTE: the number's refer to the tooth quadrant (Teeth #s
11-18,21-28,31-38,41-48) and which tooth
the abbreviations represent different points on the teeth letters are
as
follows.  For the most part the teeth points represent morph and
control points. Control points are points in the patient specific
model 160 that can be used to manipulate specific objects.
d = distal
m = mesial
l = lingual
b = buccal
r = root tip
i = incisal edge
c = cervical

abbr            landmark    Description
// ===================
LT_11m21m       11m21m      Interproximal contact point between teeth #s
11 and 21
LT_11r          11r         Tooth #11 root tip
LT_11mi         11mi        Tooth #11 mesial incisal edge
LT_11di         11di        Tooth #11 distal incisal edge
LT_11c          11c         Tooth #11 cervical
LT_11d12m       11d12m      Interproximal contact point between teeth #s
11 and 12
LT_12r          12r         Tooth #12 root tip
LT_12di         12di        Tooth #12 distal incisal edge
LT_12mi         12mi        Tooth #12 mesial incisal edge
LT_12c          12c         Tooth #12 cervical
LT_12d13m       12d13m      Interproximal contact point between teeth #s
12 and 13
LT_13r          13r         Tooth #13 root tip
LT_13i          13i         Tooth #13 incisal tip
LT_13c          13c         Tooth #13 cervical
LT_13d14m       13d14m      Interproximal contact point between teeth #s
13 and 14
LT_14r          14r         Tooth #14 root tip
LT_14l          14l         Tooth #14 lingual cusp tip
LT_14b          14b         Tooth #14 buccal cusp tip
LT_14c          14c         Tooth #14 cervical
LT_14d15m       14d15m      Interproximal contact point between teeth #s
14 and 15
LT_15r          15r         Tooth #15 root tip
LT_15l          15l         Tooth # 15 lingual cusp tip
LT_15b          15b         Tooth # 15 buccal cusp tip
LT_15c          15c         Tooth # 15 cervical
LT_15d16m       15d16m      Interproximal contact point between teeth #s
15 and 16
LT_16r          16r         Tooth #16 root tip
LT_16ml         16ml        Tooth #16 mesial lingual cusp tip
LT_16dl         16dl        Tooth #16 distal lingual cusp tip
LT_16mb         16mb        Tooth #16 mesial buccal cusp tip
LT_16db         16db        Tooth #16 distal buccal cusp tip
LT_16c          16c         Tooth #16 cervical
LT_16d17m       16d17m      Interproximal contact point between teeth #s
16 and 17
LT_17r          17r         Tooth #17 root tip
LT_17ml         17ml        Tooth #17 mesial lingual cusp tip
LT_17dl         17dl        Tooth #17 distal lingual cusp tip
LT_17mb         17mb        Tooth #17 mesial buccal cusp tip
LT_17c          17c         Tooth #17 cervical
```

SUBSTITUTE SHEET (RULE 26)

LT_17db	17db	Tooth #17 distal buccal cusp tip
LT_17d18m	17d18m	Interproximal contact point between teeth #s 17 and 18
LT_18r	18r	Tooth #18 root tip
LT_18dl	18dl	Tooth #18 distal lingual cusp tip
LT_18ml	18ml	Tooth #18 mesial lingual cusp tip
LT_18mb	18mb	Tooth #18 mesial buccal cusp tip
LT_18db	18db	Tooth #18 distal buccal cusp tip
LT_18c	18c	Tooth #18 cervical
LT_21r	21r	Tooth #21 root tip
LT_21di	21di	Tooth #21 distal incisal edge
LT_21mi	21mi	Tooth #21 mesial incisal edge
LT_21c	21c	Tooth #21 cervical
LT_21d22m	21d22m	Interproximal contact point between teeth #s 21 and 22
LT_22r	22r	Tooth #22 root tip
LT_22di	22di	Tooth #22 distal incisal edge
LT_22mi	22mi	Tooth #22 mesial incisal edge
LT_22c	22c	Tooth #22 cervical
LT_22d23m	22d23m	Interproximal contact point between teeth #s 22 and 23
LT_23r	23r	Tooth #23 root tip
LT_23i	23i	Tooth #23 incisal tip
LT_23c	23c	Tooth #23 cervical
LT_23d24m	23d24m	Interproximal contact point between teeth #s 23 and 24
LT_24r	24r	Tooth #24 root tip
LT_24l	24l	Tooth #24 lingual cusp tip
LT_24b	24b	Tooth #24 buccal cusp tip
LT_24c	24c	Tooth #24 cervical
LT_24d25m	24d25m	Interproximal contact point between teeth #s 24 and 25
LT_25	25r	Tooth #25 root tip
LT_25l	25l	Tooth #25 lingual cusp tip
LT_25b	25b	Tooth #25 buccal cusp tip
LT_25c	25c	Tooth #25 cervical
LT_25d26m	25d26m	Interproximal contact point between teeth #s 25 and 26
LT_26r	26r	Tooth #26 root tip
LT_26ml	26ml	Tooth #26 mesial lingual cusp tip
LT_26dl	26dl	Tooth #26 distal lingual cusp tip
LT_26db	26db	Tooth #26 distal buccal cusp tip
LT_26mb	26mb	Tooth #26 mesial buccal cusp tip
LT_26c	26c	Tooth #26 cervical
LT_26d27m	26d27m	Interproximal contact point between teeth #s 26 and 27
LT_27r	27r	Tooth #27 root tip
LT_27db	27db	Tooth #27 distal buccal cusp tip
LT_27mb	27mb	Tooth #27 mesial buccal cusp tip
LT_27ml	27ml	Tooth #27 mesial lingual cusp tip
LT_27dl	27dl	Tooth #27 distal lingual cusp tip
LT_27c	27c	Tooth #27 cervical
LT_27d28m	27d28m	Interproximal contact point between teeth #s 27 and 28
LT_28r	28r	Tooth #28 root tip
LT_28ml	28ml	Tooth #28 mesial lingual cusp tip
LT_28dl	28dl	Tooth #28 distal lingual cusp tip
LT_28db	28db	Tooth #28 distal buccal cusp tip
LT_28mb	28mb	Tooth #28 mesial buccal cusp tip
LT_28c	28c	Tooth #28 cervical
LT_31m41m	31m41m	Interproximal contact point between teeth #s 31 and 41
LT_31r	31r	Tooth #31 root tip
LT_31di	31di	Tooth #31 distal incisal edge
LT_31mi	31mi	Tooth #31 mesial incisal edge
LT_31c	31c	Tooth #31 cervical
LT_31d32m	31d32m	Interproximal contact point between teeth #s 31 and 32
LT_32r	32r	Tooth #32 root tip

SUBSTITUTE SHEET (RULE 26)

LT_32di	32di	Tooth #32 distal incisal edge
LT_32mi	32mi	Tooth #32 mesial incisal edge
LT_32c	32c	Tooth #32 cervical
LT_32d33m	32d33m	Interproximal contact point between teeth #s 32 and 33
LT_33r	33r	Tooth #33 root tip
LT_33i	33i	Tooth #33 incisal tip
LT_33c	33c	Tooth #33 cervical
LT_33d34m	33d34m	Interproximal contact point between teeth #s 33 and 34
LT_34r	34r	Tooth #34 root tip
LT_34b	34b	Tooth #34 buccal cusp tip
LT_34l	34l	Tooth #34 lingual cusp tip
LT_34c	34c	Tooth #34 cervical
LT_34d35m	34d35m	Interproximal contact point between teeth #s 34 and 35
LT_35r	35r	Tooth #35 root tip
LT_35l	35l	Tooth #35 lingual cusp tip
LT_35b	35b	Tooth #35 buccal cusp tip
LT_35c	35c	Tooth #35 cervical
LT_35d36m	35d36m	Interproximal contact point between teeth #s 35 and 36
LT_36r	36r	Tooth #36 root tip
LT_36ml	36ml	Tooth #36 mesial lingual cusp tip
LT_36mb	36mb	Tooth #36 mesial buccal cusp tip
LT_36db	36db	Tooth #36 distal buccal cusp tip
LT_36c	36c	Tooth #36 cervical
LT_36dl	36dl	Tooth #36 distal lingual cusp tip
LT_36d37m	36d37m	Interproximal contact point between teeth #s 36 and 37
LT_37r	37r	Tooth #37 root tip
LT_37dl	37dl	Tooth #37 distal lingual cusp tip
LT_37db	37db	Tooth #37 distal buccal cusp tip
LT_37mb	37mb	Tooth #37 mesial buccal cusp tip
LT_37ml	37ml	Tooth #37 mesial lingual cusp tip
LT_37c	37c	Tooth #37 cervical
LT_37d38m	37d38m	Interproximal contact point between teeth #s 37 and 38
LT_38r	38r	Tooth #38 root tip
LT_38db	38db	Tooth #38 distal buccal cusp tip
LT_38mb	38mb	Tooth #38 mesial buccal cusp tip
LT_38dl	38dl	Tooth #38 distal lingual cusp tip
LT_38ml	38ml	Tooth #38 mesial lingual cusp tip
LT_38c	38c	Tooth #38 cervical
LT_41r	41r	Tooth #41 root tip
LT_41di	41di	Tooth #41 distal incisal edge
LT_41mi	41mi	Tooth #41 mesial incisal edge
LT_41c	41c	Tooth #41 cervical
LT_41d42m	41d42m	Interproximal contact point between teeth #s 41 and 42
LT_42r	42r	Tooth #42 root tip
LT_42di	42di	Tooth #42 distal incisal edge
LT_42mi	42mi	Tooth #42 mesial incisal edge
LT_42c	42c	Tooth #42 cervical
LT_42d43m	42d43m	Interproximal contact point between teeth #s 42 and 43
LT_43r	43r	Tooth #43 root tip
LT_43d	43d	Tooth #43 distal interproximal contact
LT_43c	43c	Tooth #43 cervical
LT_44m	44m	Tooth #44 mesial surface interproximal contact
LT_44d	44d	Tooth #44 distal surface interproximal contact
LT_44r	44r	Tooth #44 root tip
LT_44b	44b	Tooth #44 buccal cusp tip
LT_44l	44l	Tooth #44 lingual cusp tip
LT_44c	44c	Tooth #44 cervical
LT_45m	45m	Tooth #45 mesial surface interproximal contact

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```
LT_45d         45d        Tooth #45 distal surface interproximal
contact
LT_45r         45r        Tooth #45 root tip
LT_45c         45c        Tooth #45 cervical
LT_45b         45b        Tooth #45 buccal cusp tip
LT_45l         45l        Tooth #45 lingual cusp tip
LT_46m         46m        Tooth #46 mesial surface interproximal
contact
LT_46r         46r        Tooth #46 root tip
LT_46mb        46mb       Tooth #46 mesial buccal cusp tip
LT_46db        46db       Tooth #46 distal buccal cusp tip
LT_46dl        46dl       Tooth #46 distal lingual cusp tip
LT_46c         46c        Tooth #46 cervical
LT_46ml        46ml       Tooth #46 mesial lingual cusp tip
LT_46d47m      46d47m     Interproximal contact point between teeth #s
46 and 47
LT_47r         47r        Tooth #47 root tip
LT_47mb        47mb       Tooth #47 mesial buccal cusp tip
LT_47db        47db       Tooth #47 distal buccal cusp tip
LT_47ml        47ml       Tooth #47 mesial lingual cusp tip
LT_47dl        47dl       Tooth #47 distal lingual cusp tip
LT_47c         47c        Tooth #47 cervical
LT_47d48m      47d48m     Interproximal contact point between teeth #s
47 and 48
LT_48r         48r        Tooth #48 root tip
LT_48mb        48mb       Tooth #48 mesial buccal cusp tip
LT_48db        48db       Tooth #48 distal buccal cusp tip
LT_48ml        48ml       Tooth #48 mesial lingual cusp tip
LT_48dl        48dl       Tooth #48 distal lingual cusp tip
LT_48c         48c        Tooth #48 cervical

tracedata
    {  0,   SOFT,  "TS_MIDLINE",  "Midline Soft Tissue Trace"},
    {  1,   SOFT,  "TS_REBROW",   "R Eyebrow trace"},
    {  2,   SOFT,  "TS_LEBROW",   "L Eyebrow Trace"},
    {  3,   SOFT,  "TS_REAR",     "R Ear trace"},
    {  4,   SOFT,  "TS_LEAR",     "L Ear Trace"},
    {  5,   SOFT,  "TS_REYE",     "R Eye Trace"},
    {  6,   SOFT,  "TS_LEYE",     "L Eye Trace"},
    {  7,   SOFT,  "TS_RLIP",     "R Lip Trace"},
    {  8,   SOFT,  "TS_LLIP",     "L Lip Trace"},
    {  9,   SOFT,  "TS_RN",       "R Nares Trace"},
    { 10,   SOFT,  "TS_LN",       "L Nares Trace"},
    { 11,   SOFT,  "TS_RTH",      "R Top of Head Trace"},
    { 12,   SOFT,  "TS_LTH",      "L Top of Head Trace"},
    { 13,   SOFT,  "TS_FH",       "Front of Head Trace"},
    { 14,   BONE,  "TB_RLO",      "R Orbit Trace"},
    { 15,   BONE,  "TB_LLO",      "L Orbit Trace"},
    { 16,   BONE,  "TB_RMAND",    "R Mandible trace"},
    { 17,   BONE,  "TB_LMAND",    "L Mandible trace"},
    { 18,   BONE,  "TB_RATop",    "R Arch Top Trace"},
    { 19,   BONE,  "TB_RABot",    "R Arch Bottom Trace"},
    { 20,   BONE,  "TB_LATop",    "L Arch Top Trace"},
    { 21,   BONE,  "TB_LABot",    "L Arch Bottom Trace"},
    { 22,   BONE,  "TB_MIDLINE",  "Midline Bone Trace"},

There is a single trace for occlusal table for each of the 32 teeth.
In addition, there is one trace for both dental arches that extends
along the central groove and incisal edges of teeth.
    { -1,   MAX,   "'\0'",        "'\0'"},
```

SUBSTITUTE SHEET (RULE 26)

Appendix B

The following presents cephalometric analysis that can be performed using

the clinician/consultant 125.

Steiner Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
SNA	82	
SNB	80	
ANB	2	
SND	76	
U1-NA	22	4
L1-NB	25	4
Po-NB		
Po to Li-NB		
U1-L1	131	
Occl-SN	14	
GoGn-Sn	32	

Tweed Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
FMA	22	
IMPA	86	
FMIA	62	
SNA	82	
SNB	80	
ANB	2	
Wits Appraisal ACBO		1
Occlusal Plane to Frankfurt Plane		8
Z Angle	76	
Gonion to PC		64
Menton -ANS		67

McGrann Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Palatal to Mandibular Plane	23	
Mandibular Plane to Frankfurt	25	
Y Axis	67	
SNA	82	
Mandible to Cranium		3
SNB	80	
ANB	2	
Wits Appraisal ACBO		1

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SUBSTITUTE SHEET (RULE 26)

McGrann Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Interincisal Angle	130	
IMPA	86	
Lower 1 to Nasion-B		4
B1 to A-Po Plane	75	
A1 to McNamera Line		4
Nasolabial Angle	115	
Lower Lip to Esthetic Plane		-2
Condylion-Gnathion		115
Condylion-A Point		91
Menton-ANS		67

Jaraback Skeletal Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Saddle Angle N-S-A	123 (+3)	
Articular Angle S-I-Go	143 (+6)	
Gonial Angle I-Go-Me	130 (+7)	
Sum Total	396	
Bisecting Gonial Angle Upper N-Go	52-55	3
Bisecting Gonial Angle Lower N-Go	70-75	
Anterior Cranial Base Length		71 (+/- 3)
Posterior Cranial Base Length		32 (+/- 3)
Ramus Height A-Go		44 (+/- 5)
Body Length Go-Me		71 (+/- 5)
Mandibular Body to Anterior Cranial Base Ratio		1:1
SNA (Jarabak)	78	
SNB	76-75	
ANB	2	
SN-GoGn Angle	32	
Facial Depth N-Go		
Facial Length on Y Axis		
Y Axis to Sn Angle	64-68	
Posterior Facial Height S-Go		
Anterior Facial Height N-Me		
Ratio Posterior Facial Height to Anterior Facial Height (%)		
Facial Plane Angle Sn-Me	82	

Jarabak Dental Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Occlusal Plane to GoMe Angle		
Interincisal Angle 1-1	133	
L1 to GoGn Angle	90 (+/-3)	

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Jarabak Dental Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
U1-Sn Angle	102 (+/-2)	
U1-Facial Plane (NPo)		5 (+/-2)
L1 to Facial Plane (NPo)		2 (+/-2)
Facial Esthetic Upper Lip		-1 (-4)
Facial Esthetic Lower Lip		0 (+2)

Clark Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Mandibular Arc	27.4	
Cranial Base Angle	27.8	
Facial Axis Angle	27.6	
Mandibular Plane to Frankfurt	25.2	
Cranio-Mandibular Angle	25.2	
Condylar Axis Angle	29.9	
Upper Incisor Angle	23.1	
Lower Incisor Angle	28.8	
Maxillary Plane Angle	-0.4	
Nasal Angle	7.1	
Occlusal Plane to Frankfurt	21.1	
Convexity	1.9	
B1 to A-Po Plane	1.0	
A6 Molar Position to PTV	14.5	
Lower Lip to Esthetic Plane	-1.6	

Downs Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Facial Angle	88.1	
Mandibular Plane	24.4	
Y-Axis	59.4	
Angle of Convexity	0.1	
ANB	2	
Interincisal Angle	130	
MD 1 to APo	22	1
Md 1 to Mand. Plane	90	
Mx 1 to APo		3.5
Nasion-ANS		50
Nasion-Menton		111.2
Facial Height Ratio		45

Ricketts Lateral Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Interincisal Angle	130	
Chin in Space		
Facial Axis →1	90 +/-3	

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Ricketts Lateral Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Facial Angle Depth→ 2	87 +/-3	
Mandibular Plane→3	26 +/-4	
Facial Taper→4	68 +/-3	
Lower Facial Height→5	47 +/-4	
Mandibular Arc→ 6	26 +/-4	
Convexity		
Convexity A point →7		2 +/-2
Total Facial Height	60	
Teeth		
Lower incisor to Apo →8		1 +/-2
Upper molar to PtV→10		age +3 +/-4
Mandibular incisor inclination→9	22 +/-4	
Lower lip to E Plane→11		-2 +/-2

Ricketts Frontal Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Intermolar Width (B6-B6)		54
Denture Midline		0
Max-Mand Width Left		-10.2
Max-Mand Width Right		-10.2
Denture to Jaw Midline		0
Nasal Width		26.7
Maxillary Width (J-J)		61.8
Mandibular Width (AG-GA)		76

1→ BA-CC-Po

2→ FH-N-Po

3 →MP -FH

4→

5→ANS-Xi to Xi to PM (PM = Point on anterior border of symphysis between Point B and Pogonion wher the curvature changes from concave to convex   Xi constructed point

6→Xi-PM plane to X -DC (DC=a point selected in the center of the neck of the condyle wher the basion-Nasion plane crosses it. Basion (BA) most inferior posterior p;oint oof the occipital bone

7→A-Po plane to N-Po plane

8→Tip lower incisor to APo

9→Apo-Lower incisal angle (Incisal angle formed along the vertical long axis of tooth)

10→

11→E Plane -Soft tissue tip of Nose to Soft Tissue Pogonion-Lip is lower lip

Sassouni Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
Palatal Plane Length		Not Established
Pogonion to ANS Arc		Not Established

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Sassouni Analysis		
Landmarks	Mean Angle (degrees)	Mean Measurement (mm)
B point to A Arc		Not Established
(A1) to ANS arc		Not Established
ULA Upper Lip		Not Established
Lower Incisor to Mand. Plane	86	
Upper Part of Gonial Angle	53	
Lower Part of Gonial Angle	72	
Palatal Plane to Upper Incisor	115	

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Appendix C

The following describes the tooth labeling conventions used in one

embodiment of the invention.

Most **General Dentists in the US** use this # convention. Orthodontists use this
convention when communicating w/ the General Dentist (GP) as far as
extraction, etc.
This view is as if you are looking directly at the patient's face (Your left is
the patient's right, Your right is the Patient's left)

Patient's Maxillary Right Quadrant	Patient's Maxillary Left Quadrant
Patient's Mandibular Right Quadrant	Patient's Mandibular Left Quadrant

This line represents the patient's midline

1 – 32 Adult Teeth USA 1 2 3 4 5 6 7 8 | 9 10 11 12 13 14 15
16
(Permanent)
            32 31 30 29 28 27 26 25 24 23 22 21 20 19 18
17

Permanent tooth name	Number System 1 - 32	
Maxillary Right Third molar (Wisdom)	1	
Maxillary Right Second molar (12 Year)	2	
Maxillary Right First Molar (6 Year)	3	
Maxillary Right Second Bicuspid (2nd Premolar)	4	
Maxillary Right First Bicuspid (1st Premolar)	5	
Maxillary Right Cuspid (Canine)	6	
Maxillary Right Lateral Incisor	7	
Maxillary Right Central Incisor	8	
Maxillary Left Central Incisor	9	
Maxillary Left Lateral Incisor	10	
Maxillary Left Cuspid (Canine)	11	
Maxillary Left First Bicuspid (1st Premolar)	12	
Maxillary Left Second Bicuspid (2nd Premolar)	13	
Maxillary Left First Molar (6 Year)	14	
Maxillary Left Second Molar (12 Year)	15	
Maxillary Left Third Molar (Wisdom)	16	

Upper Right
Quadrant
1 - 8

Upper Left
Quadrant
9 - 16

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Permanent tooth name	Number System 1 - 32	
Mandibular Left Third Molar (Wisdom)	17	
Mandibular Left Second Molar (12 Year)	18	
Mandibular Left First Molar (6 Year)	19	
Mandibular Left Second Bicuspid (2nd Premolar)	20	
Mandibular Left First Bicuspid (1st Premolar)	21	
Mandibular Left Cuspid (Canine)	22	
Mandibular Left Lateral Incisor	23	
Mandibular Left Central Incisor	24	
Mandibular Right Central Incisor	25	
Mandibular Right Lateral Incisor	26	
Mandibular Right Cuspid (Canine)	27	
Mandibular Right First Bicuspid (1st Premolar)	28	
Mandibular Right Second Bicuspid (2nd Premolar)	29	
Mandibular Right First Molar (6 Year)	30	
Mandibular Right Second Molar (12 Year)	31	
Mandibular Right Third Molar (Wisdom)	32	

Lower Left Quadrant 17 - 24

Lower Right Quadrant 25 - 32

a – t   Deciduous Teeth USA
(Primary)

a b   c   d e| f   g   h i j
——————————————|——————————————
t   s   r   q| p   o   n   m l k

Deciduous Tooth Name	Alpha System a - t		
Maxillary Right Deciduous Second Molar (2 Year)			a
Maxillary Right Deciduous First Molar			b
Maxillary Right Deciduous Cuspid (Canine)			c
Maxillary Right Deciduous Lateral Incisor			d
Maxillary Right Deciduous Central Incisor			e
Maxillary Left Deciduous Central Incisor			f
Maxillary Left Deciduous Lateral Incisor			g
Maxillary Left Deciduous Cuspid (Canine)			h
Maxillary Left Deciduous First Molar			I
Maxillary Left Deciduous Second Molar (2 Year)			j
Mandibular Left Deciduous Second Molar (2 Year)			k
Mandibular Left Deciduous First Molar			l
Mandibular Left Deciduous Cuspid (Canine)			m
Mandibular Left Deciduous Lateral Incisor			n
Mandibular Left Deciduous Central Incisor			o
Mandibular Right Deciduous Central Incisor			p
Mandibular Right Deciduous Lateral Incisor			q
Mandibular Right Deciduous Cuspid (Canine)			r
Mandibular Right Deciduous First Molar			s
Mandibular Right Deciduous Second Molar (2 Year)			t

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SUBSTITUTE SHEET (RULE 26)

Other Notations can be used for Missing, Supernumerary (extra)
, pontics, etc. used after the Number.

S or s   for Supernumary   P or p   for pontic

    X or x   for missing
    I or i   for Implant
    d   for deciduous

Example :   7s = supernumerary (extra) Maxillary Right Lateral
        4X = # 4 missing , missing Max. Right 2nd Bicuspid
        3 4p 5p 6 = bridge from # 3 - # 6,   (#4 & #5 are pontics)

Most Orthodontists in the USA use the following # convention:

Patient's Maxillary Right Quadrant	Patient's Maxillary Left Quadrant
Patient's Mandibular Right Quadrant	Patient's Mandibular Left Quadrant

This line represents the patient's midline

<u>1 –8 in each quadrant – Permanent Teeth USA</u>

starting w/ 1 in the middle, therefore ALL 1's are central incisors, ALL 4's are
1st bicuspids, ALL 8's are 3rd molars (wisdom teeth), etc.

    8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8

      8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8

Permanent tooth name		Number System 1-8 in each Quadrant
Maxillary Right Third molar (Wisdom)		8
Maxillary Right Second molar (12 Year)		7
Maxillary Right First Molar (6 Year)		6
Maxillary Right Second Bicuspid (2nd Premolar)		5
Maxillary Right First Bicuspid (1st Premolar)		4
Maxillary Right Cuspid (Canine)		3
Maxillary Right Lateral Incisor		2
Maxillary Right Central Incisor		1
Maxillary Left Central Incisor		1
Maxillary Left Lateral Incisor		2
Maxillary Left Cuspid (Canine)		3

SUBSTITUTE SHEET (RULE 26)

Permanent tooth name		Number System 1-8 in each Quadrant
Maxillary Left First Bicuspid (1st Premolar)		4
Maxillary Left Second Bicuspid (2nd Premolar)		5
Maxillary Left First Molar (6 Year)		6
Maxillary Left Second Molar (12 Year)		7
Maxillary Left Third Molar (Wisdom)		8
Mandibular Left Third Molar (Wisdom)		8
Mandibular Left Second Molar (12 Year)		7
Mandibular Left First Molar (6 Year)		6
Mandibular Left Second Bicuspid (2nd Premolar)		5
Mandibular Left First Bicuspid (1st Premolar)		4
Mandibular Left Cuspid (Canine)		3
Mandibular Left Lateral Incisor		2
Mandibular Left Central Incisor		1
Mandibular Right Central Incisor		1
Mandibular Right Lateral Incisor		2
Mandibular Right Cuspid (Canine)		3
Mandibular Right First Bicuspid (1st Premolar)		4
Mandibular Right Second Bicuspid (2nd Premolar)		5
Mandibular Right First Molar (6 Year)		6
Mandibular Right Second Molar (12 Year)		7
andibular Right Third Molar (Wisdom)		8

a – e in each quadrant Deciduous Teeth USA

```
e  d  c  b  a  a  b  c  d  e
_____
e  d  c  b  a  a  b  c  d  e
```
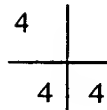
Deciduous Tooth Name		Alpha System a-e
Maxillary Right Deciduous Second Molar (2 Year)		e
Maxillary Right Deciduous First Molar		d
Maxillary Right Deciduous Cuspid (Canine)		c
Maxillary Right Deciduous Lateral Incisor		b
Maxillary Right Deciduous Central Incisor		a
Maxillary Left Deciduous Central Incisor		a
Maxillary Left Deciduous Lateral Incisor		b
Maxillary Left Deciduous Cuspid (Canine)		c
Maxillary Left Deciduous First Molar		d
Maxillary Left Deciduous Second Molar. (2 Year)		e
Mandibular Left Deciduous Second Molar (2 Year)		e
Mandibular Left Deciduous First Molar		d
Mandibular Left Deciduous Cuspid (Canine)		c
Mandibular Left Deciduous Lateral Incisor		b
Mandibular Left Deciduous Central Incisor		a

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Deciduous Tooth Name		Alpha System a-e
Mandibular Right Deciduous Central Incisor		a
Mandibular Right Deciduous Lateral Incisor		b
Mandibular Right Deciduous Cuspid (Canine)		c
Mandibular Right Deciduous First Molar		d
Mandibular Right Deciduous Second Molar (2 Year)		e

We use a short hand to diagram individual teeth or groups of teeth, example:

___| = Upper Right Quadrant |___ = Upper Left Quadrant

‾‾| = Lower Right Quadrant |‾‾ = Lower Left Quadrant

$$\frac{4 \quad | \quad 4}{4 \quad | \quad 4}$$
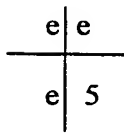
this short hand is for ALL four 1st biscuspids

$$1 \, |$$
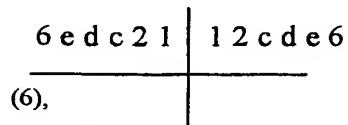
this shorthand is for the Maxillary Right Central Incisor

$$\underline{8 \, | \, 8}$$
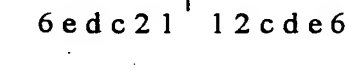
this is short hand is for both Maxillary 3rd molars

$$\frac{e \, | \, e}{e \, | \, 5}$$

this is short hand for Maxillary Right & Left Deciduous 2nd molars, Mandibular Right Deciduous 2nd molar and the Mandibular Left Permanent 2nd bicuspid

$$\frac{6\,e\,d\,c\,2\,1 \quad | \quad 1\,2\,c\,d\,e\,6}{(6), \qquad | \qquad}$$

6 e d c 2 1   1 2 c d e 6

d)

This is short hand for ALL four Permanent 1st Molars

ALL four Deciduous 2nd & 1st Molars   (e &

ALL four Deciduous cuspids (canines) (c)
ALL four Permanent Lateral incisors   (2)

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ALL four Permanent Central Incisors   (1)

Other short hand used   UR = Upper Right
                           UL = Upper Left
                           LR = Lower Right
                           LL = Lower Left

                           Followed by tooth # (Ex: UR1 = Upper Right

Central Incisor

UR8 UR7 UR6 UR5 UR4 UR3 UR2 UR1 | UL1 UL2 UL3 UL4 UL5 UL6 UL7 UL8

LR8 LR7 LR6 LR5 LR4 LR3 LR2 LR1 | LL1 LL2 LL3 LL4 LL5 LL6 LL7 LL8

Permanent tooth name		Number System 1-8 in each Quadrant
Maxillary Right Third molar (Wisdom)		UR8
Maxillary Right Second molar (12 Year)		UR7
Maxillary Right First Molar (6 Year)		UR6
Maxillary Right Second Bicuspid (2nd Premolar)		UR5
Maxillary Right First Bicuspid (1st Premolar)		UR4
Maxillary Right Cuspid (Canine)		UR3
Maxillary Right Lateral Incisor		UR2
Maxillary Right Central Incisor		UR1
Maxillary Left Central Incisor		UL1
Maxillary Left Lateral Incisor		UL2
Maxillary Left Cuspid (Canine)		UL3
Maxillary Left First Bicuspid (1st Premolar)		UL4
Maxillary Left Second Bicuspid (2nd Premolar)		UL5
Maxillary Left First Molar (6 Year)		UL6
Maxillary Left Second Molar (12 Year)		UL7
Maxillary Left Third Molar (Wisdom)		UL8
Mandibular Left Third Molar (Wisdom)		LL8
Mandibular Left Second Molar (12 Year)		LL7
Mandibular Left First Molar (6 Year)		LL6
Mandibular Left Second Bicuspid (2nd Premolar)		LL5
Mandibular Left First Bicuspid (1st Premolar)		LL4
Mandibular Left Cuspid (Canine)		LL3
Mandibular Left Lateral Incisor		LL2
Mandibular Left Central Incisor		LL1
Mandibular Right Central Incisor		LR1
Mandibular Right Lateral Incisor		LR2
Mandibular Right Cuspid (Canine)		LR3
Mandibular Right First Bicuspid (1st Premolar)		LR4
Mandibular Right Second Bicuspid (2nd Premolar)		LR5

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Permanent tooth name		Number System 1-8 in each Quadrant
Mandibular Right First Molar (6 Year)		LR6
Mandibular Right Second Molar (12 Year)		LR7
Mandibular Right Third Molar (Wisdom) .		LR8

Could also be for Deciduous teeth using URa , LL b, etc.

Deciduous Tooth Name		Alpha & numeric System UR format a - e
Maxillary Right Deciduous Second Molar (2 Year)		UR e
Maxillary Right Deciduous First Molar		UR d
Maxillary Right Deciduous Cuspid (Canine)		UR c
Maxillary Right Deciduous Lateral Incisor		UR b
Maxillary Right Deciduous Central Incisor		UR a
Maxillary Left Deciduous Central Incisor		UL a
Maxillary Left Deciduous Lateral Incisor		UL b
Maxillary Left Deciduous Cuspid (Canine)		UL c
Maxillary Left Deciduous First Molar		UL d
Maxillary Left Deciduous Second Molar (2 Year)		UL e
Mandibular Left Deciduous Second Molar (2 Year)		LL e
Mandibular Left Deciduous First Molar		LL d
Mandibular Left Deciduous Cuspid (Canine)		LL c
Mandibular Left Deciduous Lateral Incisor		LL b
Mandibular Left Deciduous Central Incisor		LL a
Mandibular Right Deciduous Central Incisor		LR a
Mandibular Right Deciduous Lateral Incisor		LR b
Mandibular Right Deciduous Cuspid (Canine)		LR c
Mandibular Right Deciduous First Molar		LR d
Mandibular Right Deciduous Second Molar (2 Year)		LR e

International Teeth # System

11 – 18, 21 – 28, 31 – 38, 41 – 48   International Adult teeth

Each Quadrant numbered by 1st #

1   = Maxillary Right   Quadrant 1
Quadrant 2

2 =Maxillary Left
3 = Mandibular Left   Quadrant 4
Quadrant 3

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4 = Mandibular Right

Then tooth # 1 – 8

```
            18 17 16 15 14 13 12 11│ 21 22 23 24 25 26 27
28
          ─────────────────────────┼──────────────────────
            48 47 46 45 44 43 42 41│ 31 32 33 34 35 36 37
38
```

International Deciduous Teeth

Quadrants 5 – 8
6

	Quadrant 5	Quadrant

Quadrant 8

Quadrant 7

Then tooth # 1 - 8

```
            58 57 56 55 54 53 52 51│ 61 62 63 64 65 66 67
68
          ─────────────────────────┼──────────────────────
            88 87 86 85 84 83 82 81│ 71 72 73 74 75 76 77
78
```

Permanent tooth name			First # = Quadrant # second # = tooth #	
Maxillary Right Third molar (Wisdom)			18	one-eight
Maxillary Right Second molar (12 Year)			17	one-seven
Maxillary Right First Molar (6 Year)			16	one-six
Maxillary Right Second Bicuspid (2nd Premolar)			15	etc.
Maxillary Right First Bicuspid (1st Premolar)			14	
Maxillary Right Cuspid (Canine)			13	
Maxillary Right Lateral Incisor			12	
Maxillary Right Central Incisor			11	
Maxillary Left Central Incisor			21	two-one
Maxillary Left Lateral Incisor			22	etc.
Maxillary Left Cuspid (Canine)			23	
Maxillary Left First Bicuspid (1st Premolar)			24	
Maxillary Left Second Bicuspid (2nd Premolar)			25	
Maxillary Left First Molar (6 Year)			26	
Maxillary Left Second Molar (12 Year)			27	
Maxillary Left Third Molar (Wisdom)			28	

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Permanent tooth name			First # = Quadrant # second # = tooth #	
Mandibular Left Third Molar (Wisdom)			38	three-eight
Mandibular Left Second Molar (12 Year)			37	etc.
Mandibular Left First Molar (6 Year)			36	
Mandibular Left Second Bicuspid (2nd Premolar)			35	
Mandibular Left First Bicuspid (1st Premolar)			34	
Mandibular Left Cuspid (Canine)			33	
Mandibular Left Lateral Incisor			32	
Mandibular Left Central Incisor			31	
Mandibular Right Central Incisor			41	four-one
Mandibular Right Lateral Incisor			42	etc.
Mandibular Right Cuspid (Canine)			43	
Mandibular Right First Bicuspid (1st Premolar)			44	
Mandibular Right Second Bicuspid (2nd Premolar)			45	
Mandibular Right First Molar (6 Year)			46	
Mandibular Right Second Molar (12 Year)			47	
Mandibular Right Third Molar (Wisdom)			48	
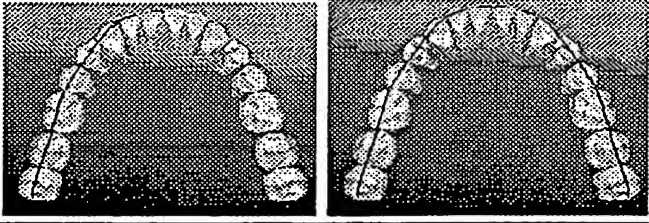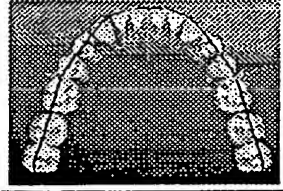
Deciduous Tooth Name		Quadrant # first then tooth letter
Maxillary Right Deciduous Second Molar (2 Year)		1e
Maxillary Right Deciduous First Molar		1d
ight Deciduous Cuspid (Canine)		1c
Maxillary Right Deciduous Lateral Incisor		1b
Maxillary Right Deciduous Central Incisor		1a
Maxillary Left Deciduous Central Incisor		2a
Maxillary Left Deciduous Lateral Incisor		2b
Maxillary Left Deciduous Cuspid (Canine)		2c
Maxillary Left Deciduous First Molar		2d
Maxillary Left Deciduous Second Molar (2 Year)		2e
Mandibular Left Deciduous Second Molar (2 Year)		3e
Mandibular Left Deciduous First Molar		3d
Mandibular Left Deciduous Cuspid (Canine)		3c
Mandibular Left Deciduous Lateral Incisor		3b
Mandibular Left Deciduous Central Incisor		3a
Mandibular Right Deciduous Central Incisor		4a
Mandibular Right Deciduous Lateral Incisor		4b
Mandibular Right Deciduous Cuspid (Canine)		4c
Mandibular Right Deciduous First Molar		4d
Mandibular Right Deciduous Second Molar (2 Year)		4e

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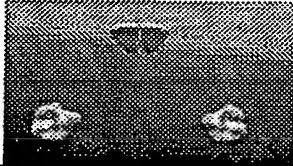
Appendix D
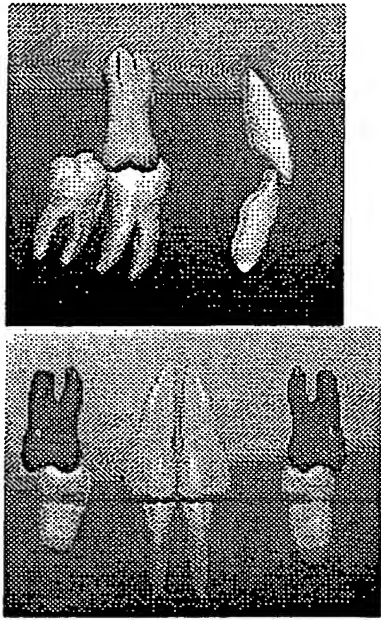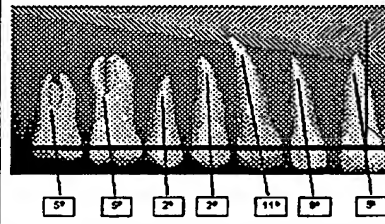
The following describes a tooth auto-alignment strategy used in the clinician/consultant 125. The clinician/consultant 125 can use the following procedure in determining an appropriate treatment for a patient.

1.   Generate tooth alignment template (arch wire).
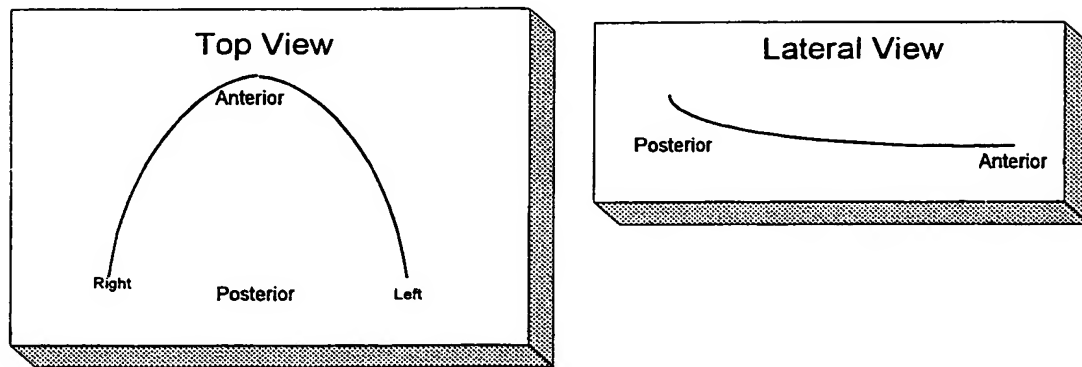
Tooth Wire Alignment	
	Fit tooth alignment wire to the dental arch
	Establish midline and first molar locations on the wire.

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Set incisors	Set teeth #s 11 and 21 on opposite sides of the midline mark for the maxilla and set teeth #s 31 and 41 on the opposite sides of the mandibular Midline.
Set Molars	Set the mesial surfaces of first molars on molar wire locations.
Set other Teeth	Align the remainder of the teeth. The mesial contact of tooth n to contact distal contact of adjacent tooth n+1 except for the midline teeth #s 11,21,31 and 41. The mesial contact on tooth #21 contact the mesial contact on tooth #11. Similarly the mesial contact on tooth #31 contacts the mesial contact on tooth # 41.
Space Conflict	What to do if there is a **space conflict**, i.e., too much tooth mass between the mesial of the first molar and the distal of the central incisors to fit on the wire. **Option 1.** Maintain mesial and distal contacts on the wire but have the teeth overlap each other. Produce feedback about quantity of overlap (for each tooth and combined overlap). **Option 2.** Do not allow teeth to overlap and do not constrain the contact to the wire. Produce a best fit to the space trying to conform to the wire.

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Molar Interarch Relationships	
• **Class I Molars** 	• Mesiobuccal Cusp of the upper first molar should occlude in the groove between the mesial and distal buccal cusps of the lower 1ˢᵗ molar • Mesial Lingual Cusp Tip of Maxillary 1ˢᵗ molar fits into central fossa in lower molar • Distal Buccal Cusp Tip of Mandibular molar first Molar fits into Central fossa of Upper 1ˢᵗ Molar • The crown of the upper first molar must be angulated so that its distal marginal ridge occludes with the mesial marginal ridge of the lower second molar

Mesiodistal Crown Angulation

Mesiodistal Crown Angulation	For the occlusion to be considered normal, the gingival part of the long axis of the crown must be distal to the occlusal part of the axis. The degree of angulation depends on the type of tooth.
Mesiodistal Crown Angulation for Various types of upper teeth	

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Labiolingual Crown Inclination
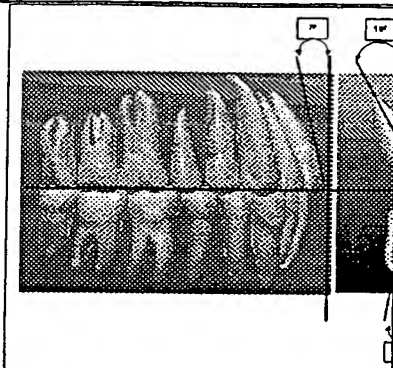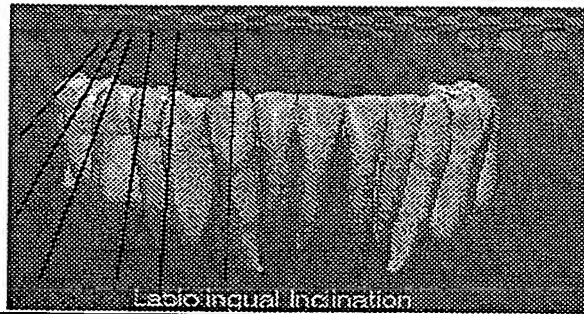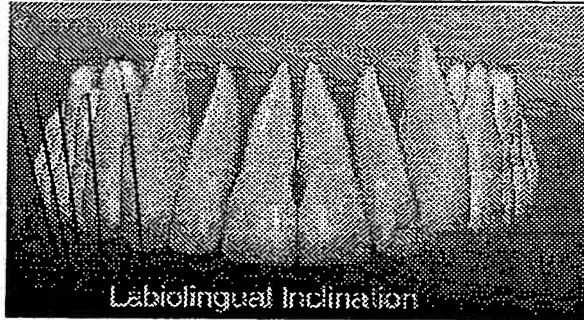
Tooth Rotations
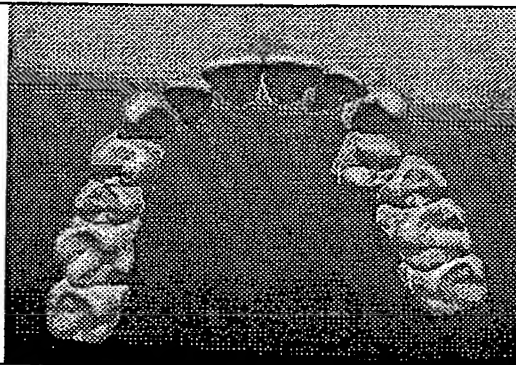
None of the teeth should be rotated. Rotated molars and premolars occupy more space in the dental arch than normal. Rotated incisors may occupy less space than those correctly aligned. Rotated canines adversely affect esthetics and may lead to occlusal interferences.

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Tooth Spacing

If there are no anomalies in the shape of the teeth, or inter-maxillary discrepancies in the mesiodistal tooth size, the contact points should abut in normal occlusion.

Curve of Spee
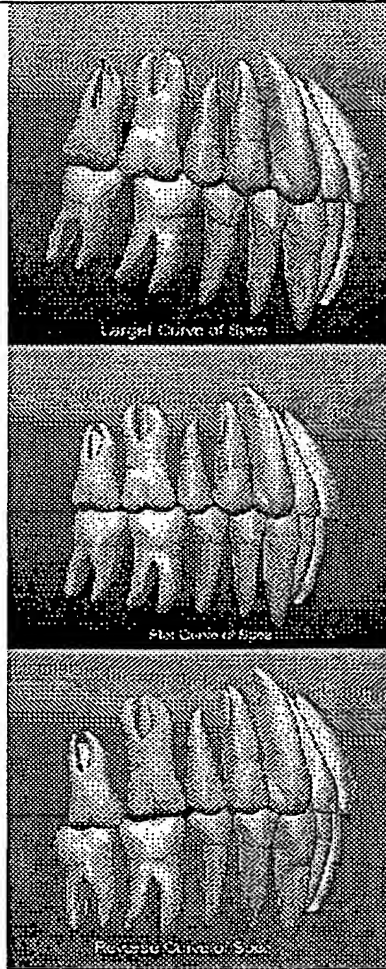
- An excessive curve of Spee restricts the amount of space available for the upper teeth, which must then move toward the mesial and distal, thus preventing correct intercuspation.
- A normal occlusion has a flat occlusal plane (according to Andrews, the mandibular curve of Spee should not be deeper than 1.5mm)
- A reverse curve of Spee creates excessive space in the upper jaw, which prevents development of a normal occlusion.

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Appendix E

The following describes an Roth analysis that can be performed using the clinician/consultant 125 and can be particularly helpful in the tooth alignment treatment.

Feature	Description
Occlusal plane	Distobuccal cusps of lower first molars (36 and 46) and a midpoint between the mesioincisal edges of #s 31 and 41.
Crown Long axis	A line formed between the gingival height of contour and cusp tip for the bicuspids and cuspids
	A line formed between the gingival height of contour and *** the for incisor teeth
	A line formed between the gingival height of contour and the origin of the groove between the buccal cusps on the molars.
Bracket placement	Brackets are placed at the mid-crown point on this crown long axis. Mid-crown equals a point midway between the height at the cusp tips and the gingival height of contour. This is true for all teeth except the maxillary lateral incisors (12 and 21). #s 21 and 12 are set o.5 mm short of the crown midpoint but the final result will have the incisal edge of these teeth 1 m short of the adjacent teeth.
Overbite	4 mm
Canine	To contact point
Overjet	2-3 mm
Canine	1 mm

<u>Appendix F</u>

The following describes the specifications of various embodiments of the invention.

Description of Product Features

Cephalometric Module

This module has been designed to assist with patient analysis, treatment planning and patient education for orthodontists, dentists that perform orthodontics and oral surgeons that perform orthognathic surgery. This module will provide the full range of analysis, modelling and treatment features currently expected with all existing 2D software packages. In addition, this module will allow the soft and hard tissues to be accurately captured and photorealistically displayed and analyzed in three dimensions. Unique algorithms will then be accessed to perform a number of functions with the captured data.

| Normal Stock Object | The stock objects will be used for model matching and used as a template for **rapid conversion of the patient input data to a 3-D model**. These stock objects will include the jaws, teeth, and soft tissues of the face. The stock objects can be constructed to represent NORMAL for the modeled anatomy. In addition, other stock objects could be designed to provide a closer starting point for common types of anatomical variation or pathology. These variations may include size, sex and facial form (Angle's Class I,II and III). Stock objects will be constructed from a wire frame with a relatively small polygon count. The vertices of the wire frame can be strategically located to allow for the |

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subsequent modifications that will allow for rapid customization to adapt to the patient's input data. In the jaws, the stock objects can have a minimum # of "tie down points" that corresponds to "landmark locations". The minimum # of tie down points on a tooth may include those that allow for rapid modification in height, mesiodistal and buccolingual width, and angulation.

The wire frame can be mutable. The wire frame can possess a logical behavior among the neighboring wire frame intersects or vertices. That is, when the wire frame is mutated by the end user all of the intersects that are changed and their neighbors can respond in a logical fashion. Landmark groupings can be able to be segmented and moved to a new location to simulate treatment or growth. The movement of these segmented landmarks can occur through data input or manual "Drag and Drop,"
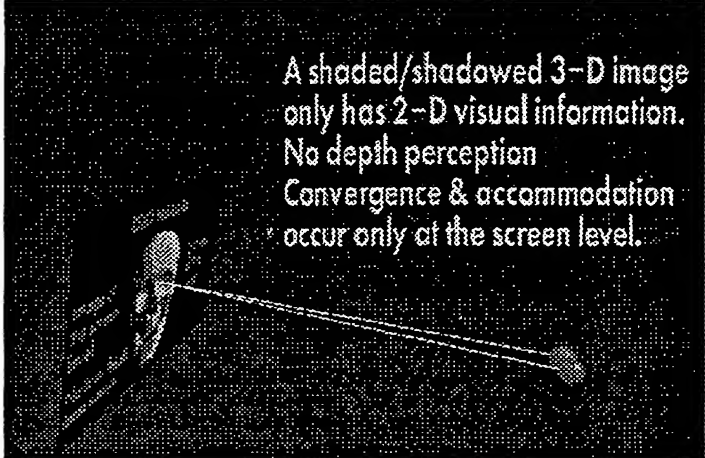
There can be a method for rapid or automatic registration of the stock object with the input data. The input data can include photographs, x-rays, a previously rendered patient 3-D data set.

The stock objects can have a spatial association with a data base. The data base will record the 3-D spatial attitude of the stock object and will record modifications of the stock object. The data base will track the landmark locations and any other changes that relate to the original polygon size and form.

Object-Oriented Data Base	This is a feature that the average user of the software may not fully appreciate. However, as the framework of software design, it has many advantages from MedScape point of view. the MedScape product line deals with physical entities such as patients and anatomical structures of the face. It produces images from these objects, extracts measurements and produces models of them. It also produces such end-user data products as growth prediction and treatment plans. The underlying data structure that can define and relate all these entities in a unified fashion is **an object oriented database**. The time spent initially on a framework for careful definition of the object classes and their relations in such a database will save tremendous amount of effort and cost in the following developments. In addition to producing reusable computer programs, this approach will facilitate definition and integration of the work by multiple teams, namely MedScape R&D contractors as currently envisioned.
	Typical examples of objects are a patient, a digital image, a specific mandible, the 3-D model of a specific mandible, a "normal" mandible, a treatment plan, etc. The specific instances of these objects are stored in the database as rows of various tables, where each table represents the object class. Each class is identified by its properties and methods (procedures that are applied to them). Each software development team will concentrate on specific object classes assigned to it with the goal of producing class libraries that expose the properties and methods of each object to all development teams for final integration.

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3-D ACCURACY	Although accuracy numbers for the so called "nominal" conditions can be provided, the accuracy of position and orientation measurements made from one or more images of an object can vary significantly depending on a number parameters. Some of these parameters are inherent to the image sensor resolution and noise which can be considered fixed and are determined off-line. However, an even larger number of these parameters depend on the geometry and size of the very object being measured, and the geometric setup of the imaging sensors. These "variable" parameters of course mean that the accuracy can not be quoted as a unique specification for a measurement system. However, theoretical error bounds can be internally computed from calibration data, camera resolution, and other system parameters for a specific measurement scenario. The proposed software will include the necessary models and algorithms to compute these theoretic error bounds and provide them as part of the measurement results. For example in the case of landmark position measurements, for each measured landmark the software outputs the ellipsoid that represents the error uncertainty in three dimensions. In this way the user is given a yard stick by which the accuracy of each measurement results can be judged. In the case of cephalometric landmark measurements, submillimeter accuracy was predicted and to some extent experimentally validated by exercising these analytic error models. A specific R&D task is to validate the error models using more complete experimentation.
MODEL MATCHING	The starting point for modeling an object from multiple images is to retrieve a "stock" or normal version of that

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	object model from the database, and use it as a guide for designating the landmarks and traces in multiple views. The discrete features measured from the actual images are then used to modify the stock model to obtain the desired object model. This process requires matching of the stock object model to the actual measurements. The model matching is based on a discrete and limited set of features which will uniquely define a stock object. The software will be able to match the stock model by moving these limited features without distorting the model into a different object.
IMAGE FIDELITY	The MedScape software typically operates on high quality images. To avoid dealing with large file size, the software uses image compression using the highest compression ratio for which the required image quality is achievable. The image quality is preserved both in terms of being visually acceptable, and in terms of completely preserving the features that are used for 3-D measurements and modeling. For 3-D rendering using photographic texture mapping, the resolution requirement of the rendered result determines the resolution of images at acquisition time
SPATIAL CALIBRATION	The spatial calibration of an image is addressed as part of the overall geometric calibration of the system. This calibration provides a precise and quantitative model of the overall imaging chain including the position and orientation of the imaging sensors relative to the measurement coordinates, the internal geometry of the sensors, and the sampling parameters of the sensor plane to form the final array of pixels. Nonlinear transformations due to perspective and, when applicable, due to optics are modeled and compensated for by the calibration process.
IMPROVED ASSOCIATION	Through photogrammetry computations combined with local image analysis algorithms, the software automatically

	establishes correspondence of two or more points used for triangulation. This will minimizes the user effort of designating the corresponding points in different views based on visual cues. This automation is achieved by taking into account the geometric constraints imposed by both the imaging system and the object being modeled.
3-D Display

A shaded/shadowed 3-D image only has 2-D visual information. No depth perception Convergence & accommodation occur only at the screen level.

3D display refers to the mode of 3D visualization on a computer screen. The reason MedScape was formed, is to give doctors a convenient, fast and user friendly way to gain accurate 3D information for diagnosis and treatment planning. Today's "state-of-the-art", in orthodontics, orthognathic surgery and plastic and reconstructive surgery diagnosis, is two-dimensional. True three-dimensional visualization and manipulation of the 3D data set is essential for accurate diagnosis and treatment planning.

The 3D display allows for the visualization of the 3D data base (created from photos, models, X-rays, etc). This 3D visualization allows for 1) Perspective 3D viewing with shading, shadowing and monocular depth cues. 2) Straight on 3D Stereoscopic viewing and 3) Ability to view the 3D data set in a 45 degree 3D Stereoscopic viewing mode (allows for 50% more visual information). |

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The 3D display of the 3D data set can include the following information:

1) Display dimensionally accurate representation of the patients anatomy. (face, facial contours, teeth, gingival tissue, bony anatomy via ceph X-ray or CT, MRI (wire frame and rendered), etc.)

2) A consistent cartesian coordinate system. A right handed Cartesian Coordinate System is defined as: Looking at Front of an object (ex. front of the face)

X axis - Horizontal with Positive X to the Right,

Y axis - Vertical with positive Y up,

Z axis - In/Out with positive toward the viewer
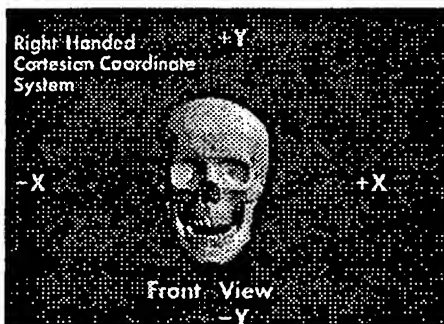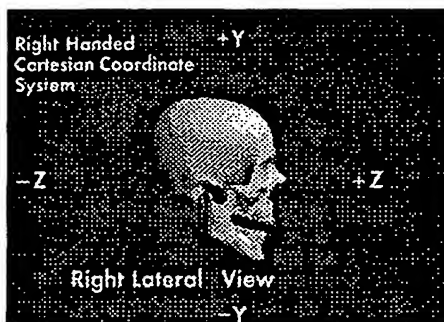
All data sources set to this right handed Cartesian Coordinate System.

3) An X,Y,Z, analog in computer display to aid viewer in orientation of 3D data set. For 3D perspective & 3D Stereoscopic

4) Rotation of the 3D Data Set in all 3 planes of space and the ability to control the roll, pitch & yaw movements around these

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axes (6 degrees of freedom). The ability to see the 3D data set from any angle or view.

5) Be able to lock the mouse so the object can be rotated in only one axis at a time and in real time.

6) Be able to easily go back to the original orientation of the data set (example - Frontal View).

7) The user can define and control the rotation of the data set precisely. (1 degree Rotation or smaller)

8) The user should be able to define a rotational pattern around one, two, or three axes, together or independently.

9) The user should be able to move the 3D model in real time:

      1. up/down,

      2. right /left, &/or

      3. in/out. (Stereoscopic vs larger/smaller or Z buffer)

10) See any virtual view at any angle Predefined views 1) Frontal, 2) Right Lateral, 3) Left Lateral, 4) SMV, 5) 45 degree right, 6) 45 degree left, 7) smile, 8) lips in repose vs lips closed. (ABO Requirements)

11) Animation in perspective 3D and in Stereoscopic 3D. (Example: open/closed animation to evaluate deviation on opening, asymmetry, etc. animate mandibular movements associated with jaw tracking).

12) The 3D display should allow for user controlled transparency of facial soft tissue to show underlying teeth and skeletal structure relationship. Transparency should be controlled by a slide bar from 0% - 100% and have predefined 20%, 40%, 60%, 80%, for quick acquisition.

13) Lighting of the 3D data set should be predefined to give the best brightness, contract, etc. Real time lighting changes should be possible to gain better 3D view. Especially important with 3D Stereoscopic viewing on high contrast areas as it gives poor results to the stereoscopic effect. In Stereoscopic mode the lighting should allow for the Stereopairs to be lighted the same. Eliminate difference in lighting of the two separate views , creates ghosting.

14) A Reference plane should be available to show the drawing plane, etc.

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15) The use of zoom, magnify, scaling, set axis, split objects, move segments, trim, grasp objects should be available and user controlled.

16) The software 3D program should show the wireframe, quick render and full render of the 3D data set. Also render a window should be available to render only an area of interest.

17) The 3D Display should use the photographs from which the wireframes are generated to create the photorealistic textures.

18) The camera setting should be predefined. Other setting can be included as: scene camera, director camera, pan, tilt, Roll, Dolly, etc.

19) 3D display allow for import/export of Model files: (.MDL, .DXF, .IGS, .3DS, other)

20) Import/Export of picture formats: (.BMP, .TGA, .GIF, .TIF, .PCX, other).

21) The 3D display should allow for facial topography visualization and measurement. Facial topography contours have certain patterns that differ from people considered "Beautiful" vs "Ugly" vs "Normal". Subtle differences in the nasal area, Zygomatic area (cheek bone), Lip contour, submental fold and chin area. Facial topography will be more evident in stereoscopic 3-D visualization.

Features that are used to describe beauty:

1. Cheek: high VS. Flat
2. Chin: asymmetry, prominence, deficiency, cleft
3. Lips: Full, thin, protrusive, retrusive, commisure, vermilion border, ethnic considerations.
4. Nose: Size, width, flaring, alar base, nares, dorsal hump, nasal tip, symmetry, nasal cartilage deviation
5. Smile: gummy, deficient, long face, short face, symmetry
6. Facial: Proportional thirds, symmetry
7. eyes: Symmetry, high, low, prominent vs. recessed.
8. Glabella: Prominent vs. deficient
9. Ears: Symmetry, size, vertical position, morphology

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3D Steroscopic Display	
	The human visual system is composed of two eyes with a horizontal interocular distance of approximately 65mm. This Horizontal off set of the eyes allows for each eye to "see" a slightly different view in the "real world". This retinal disparity creates Binocular vision in which the brain fuses these two slightly different views into a single view with visual depth perception. Binocular vision allows for visual and intuitive understanding of depth. **Convergence** of the eyes are controlled by muscular effort that sends proprioceptive input to the neurological system to help determine depth and position of objects. **Accommodation** (or focusing) of the lens of the eyes also presents a proprioceptive mechanism to determine depth information.
	Human Binocular vision is also closely associated with proprioceptive feedback from the tactile sense (Haptic = touch and Prehensile = reach and grasp).
	Retinal disparity is mimicked by creating parallax on the screen. Parallax is the horizontal offset of two separate pictures of the same scene. Parallax can be controlled to create the image behind the screen (positive parallax), at the screen plane (Zero Parallax) or in front of the screen (negative parallax).

Negative parallax would be the best choice for 3D stereoscopic viewing of cephalometric images.
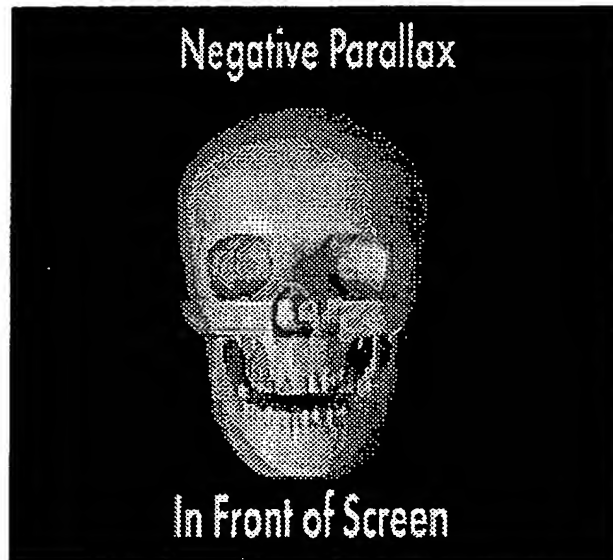
Stereoscopic 3D imaging allows for all 3 planes of space to be viewed, simultaneously. This is a clear and important difference between 3D Stereoscopic viewing and 3D perspective viewing. When stereoscopic 3D visualization is added to motion parallax (such as rotation of the object) there is an enhancement of visual depth.

The 45 degree angular stereoscopic viewing allows the operator to view 50% more of the image. This is an even greater reason to use Stereoscopic viewing. Again motion parallax (rotation) adds even more visual reference. It allows for improved visualization of the Z axis information.

Any 3D visual information can be created in a 3D Stereoscopic mode to further enhance to visual ability to understand 3D relationships of anatomy. When motion parallax is also added even greater visual depth information is present.
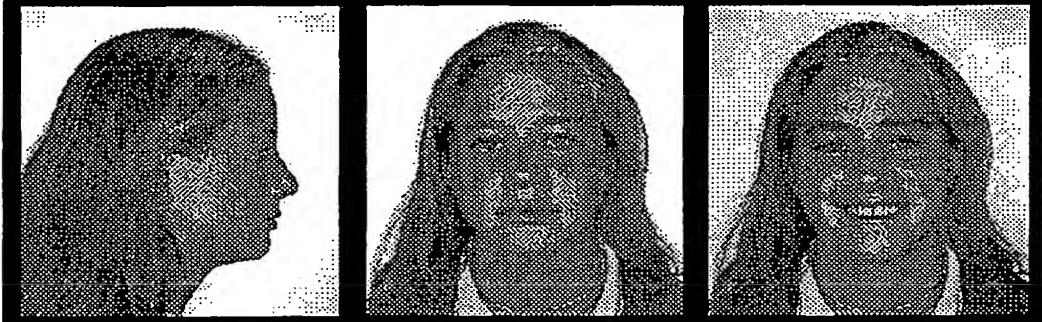
vantages of 3D Stereo vs perspective 3D vs 2D:

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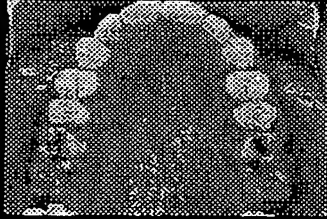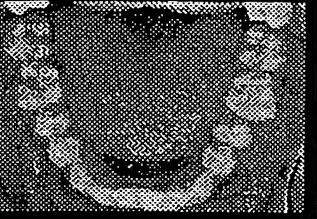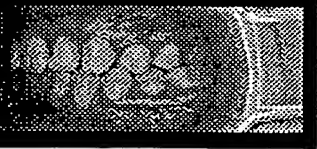
	Once the 3D model is created (patient face, teeth, skeletal structure), the software program can create the appropriate "stereo pairs" for 3D Stereoscopic viewing. Lighting (brightness, contrast, shadows, etc), can be controlled. The software can create the appropriate parallax on the screen to create the stereoscopic image on the screen when viewed with the appropriate viewing lenses (anaglyph, polarized, field sequential). In order to view stereoscopically on a computer monitor, one can present the two separate images to the corresponding retina in each eye. Anaglyph uses Red & Blue lenses so that each eye only sees the image it is suppose to see. There is some limitation on using colored images with the anaglyph mode. Other mechanisms such as polarized or field segmental are available. Precise control of the vertical and horizontal parallax is critical. Stereo viewing of angular, linear, planes, angles, points, and volume is important. Full color can be done with anaglyph (synthonics) but problems do arise with red, blue and green colors that are part of the image. True full color is best seen with polarized or field sequential (LCD shutters). Field sequential can be 60 or 120Hz. The image flicker can only be eliminated with the 120 Hz. Another advantage of field sequential is tracking devices can be incorporated to allows the viewer to visualize the 3D scene from multiple viewing angles. The multiple viewing angle is an advantage over fixed viewing angle required by anaglyph or polarized viewing techniques.
Models as a Data Source	The molds of the teeth give a physical model upon which arch length and treatment decisions are made. These models can be mounted on an articulator or not mounted. The articulated mounted models give a more true 3D relationship of the teeth to

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	skeletal reference planes. These physical models can be digitized or photographed in order to enter the 3D data information to create the model analysis in the computer and also as a model to be integrated to the face and skeleton from photo & X-ray data sources. The voxel view scanner with confetti projector can be used to photograph the physical models of the teeth and to create the 3D data points for the creation of a wireframe and a photorendered model of the teeth for computer manipulation and integration to the skeletal anatomy and facial topography. A very accurate 3D data set could be made by sectioning, via microtome, a copy of the physical molds of the teeth (in microns) and taking sequential pictures of the "cross sections". These pictures of the cross sections can then be combined into a very accurate 3D data set for use as a 3D model in computer memory or for storage on CD ROM.
Data Fusion	Data fusion allows data acquired through independent input devices to be combined (fused) into a single 3-D data base. This requires that all input devices be calibrated to allow for the creation of "dimensionally true" data. In addition, all data sets can be cross-calibrated to use a common 3-D co-ordinate system. The device calibration and the cross-calibration of data sets should be automatic to facilitate the speed of data fusion. The data fusion will occur through the image management system (IMS). Independent data sets will have a mathematical, geometrical or spatial relationship to each other that can be calibrated or related through the process of data fusion. These mathematical, etc. relationships will be monitored through the

	use of the IMS data base.
FDA Approval	There has been a push in recent years by the ADA and FDA to have all medical devices, including soft ware, FDA approved. This approval is not required at this time but is desirable. In essence the software can be approved to validate that it can do what MedScape claims it can do. The software can provide safety features to assure that the patients anatomy is not be misrepresented . There should be a record of all digital alterations of the original input data.

Input Data Sources for Cephalometric Module	
Cephalometric	The standard cephalometric technique requires a 60 inch source to mid- cephalostat distance and a 15 cm from the mid ceph. to film plane distance. The beam is projected in the horizontal plane and perpendicular to the film plane. The cephalostat orients and stabilizes the head through the use of ear rods. The standard cephs are acquired from the lateral and frontal directions. Standard and non-standard cephalometric images can be utilized for MedScape software. Non standard cephs can alter any of the above parameters. Calibration markers can be used. These calibration markers will calibrate the imaging device, be used for cross-calibration of the data sets and may be used to calibrate the gray scale. We should allow the orthodontists to have output that conforms to the standard projections.
Facial Photographs	Photographic standards have been formed by the American Board of Orthodontics (ABO). These standards specify the

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input device and the output (size, orientation and included anatomy). For the MedScape product this ABO output can be a minimum requirement so that orthodontists satisfy the ABO requirements. A 35 mm format has been the industry input device standard for years but the ABO has recently allowed the use of digital input devices. The output is ¼ size and includes a full frontal face view, lateral face view and a smile view. MedScape may require other projections angles in order to build the 3-D model but can have the standard photographs for orthodontists. These images can be calibrated for color, dimensions, and cross-calibration with the other input devices.

Intra-Oral Photographs	The ABO has extended standards for intra-oral photographs. The standard projection angles for intra-oral photographs include full frontal with teeth in occlusion, right and left lateral projections of the teeth and maxillary and mandibular occlusal projections. The output images are at full size (1:1 ratio). MedScape may require other projections angles to build the 3-D model but can have the standard photographs for orthodontists. These images can be calibrated for color, dimensions, and cross-calibration with the other input devices.

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GAGAN, MS. SARAH
08/20/96   AGE: 13.9
TERECITA DEAN, D.D.S.

CR Recordings	Centric Relation (CR) refers to the 3-D spatial relationship of the mandible relative to the maxilla when the condyles are "seated" in their fossa and the teeth are at an "initial contact" point. CR is used by many clinicians as a treatment planning, treatment reference and treatment starting point. All of our visual input records (photographs and radiographic images) are created when the mandible is in centric occlusion (CO). CO refers to the 3-D spatial relationship of the mandible relative to the maxilla when the teeth are closed in their habitual occlusion. The habitual occlusion allows the teeth to achieve maximum intercuspation (shortest vertical dimension of occlusion). CR may not equal CO and therefore we can be able to record both CO and CR jaw positions and mathematically convert the input data sets from CO to CR by calculating the 3D displacement of the mandible.
	Conversion from CO to CR: Acquire digital images obtained at one or more visual viewing angles for the face that has embedded tracking markers that define the 3-D spatial attitude

	of the maxilla and another set of markers that define the spatial attitude of the mandible. Take one set of images with the teeth in CO and another set in CR. The MedScape software tracks the maxillary and mandibular markers and will compute the relative changes in their spatial location (mandibular displacement). The location of these tracking markers can be spatially cross calibrated with the cephalometric 3-D input data. The mandible can be treated as a right bodyThe cephalometric landmark data that describes the mandible can be segmented from the remaining data. . The segmentation allows the mandible to be moved within the data set. The CO➔CR tracking or mandibular displacement data will be applied to the cross calibrated cephalometric data to move the mandible to a CR position for analysis and treatment planning.

Feature Description For Cephalometric Module	
Landmark ID	Landmarks can correspond with standard orthodontics landmarks, i.e., gonion, nasion, sella, pogonion, etc. These landmarks can be located in their normal position on the morphologically normal skeletal stock object and can be visually evident. These landmarks can be spatially associated to each other through the IMS data base functions. The spatially calibrated cephalometric views (H & M Associate software) can be overlaid on the stock object. The stock object will be customized to fit the cephalometric data by either drag and drop of a stock object landmark to the corresponding ceph. landmark (edited in all available projection views) or by

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	digitizing the landmarks on the ceph and then making the association and customization from the stock object through the IMS data base. A combination of the two customization methods can be used. In addition, non-landmark cephalometric data may also be associated with the stock objects. The non-landmark data of most interest are the ridge crests (j.e., orbital rims, rim of the nasal fossa, external borders of the mandible, mandibular canal, sinuses margins etc.
	The stock objects provide a visual reference of the patients anatomy and the landmarks are the data base portion of the patient's file that describe the features that are unique for that individual. Therefore, only the landmark locations need to be stored in the IMS data base. The landmark locations can serve as a set of instructions for altering the stock objects. Similarly, the transmission of patient landmark location and customizing the stock object at the receiver is more efficient method then transmitting a customized stock object. Use the IMS data base to compile landmark location data to be used to establish normative data for 3D cephalometric analysis and for upgrading the stock model.
2D Analysis and 2 D Normative Data	A 2D orthodontic cephalometric analysis is based on comparison of the patients' data with 2D normative data bases that have existed for decades. 2D normative data bases include: Burlington growth study, Bolton/Broadbent, Rocky Mountain Data Systems, Michigan Growth Study, to name a few. 2D analysis include: Steiner Analysis, Downs Analysis, Ricketts, Tweed, Alabama, RMDS, Wits, Owens, etc. 2D template analyses are normative 2D visualizations that are overlayed

	over the patients tracing for immediate visual information of deviations from the norms. Standard deviations from the norm are included in most computerized 2D analysis for comparison. One, two & three standard deviations from the "norm" are shown both numerically and graphically. 2D anatomical landmarks of anatomy are well defined in the literature and include: Sella, Nasion, Point A, Point B, pogonion, menton, gnathion, porion, orbitale, articularie, condylion, gonion, etc.

LATERAL CEPHALOMETRIC ANALYSIS POINTS
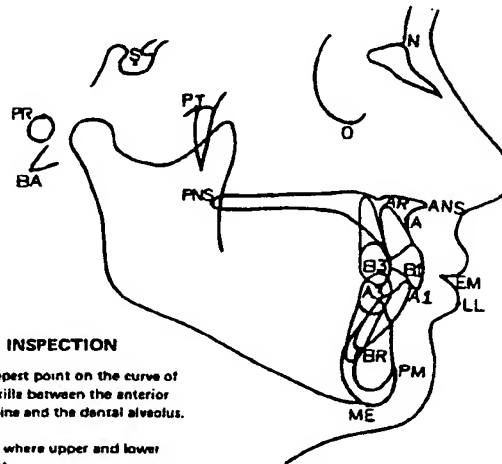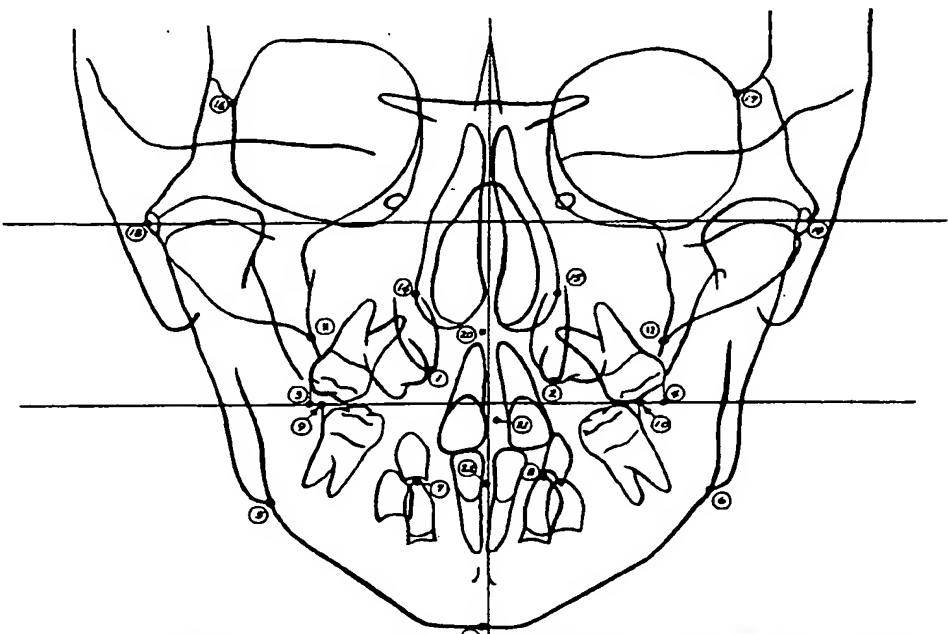
POINTS SELECTED BY INSPECTION

A -- A Point	The deepest point on the curve of the Maxilla between the anterior nasal spine and the dental alveolus.	
Em - Embrasure	A point where upper and lower lips meet.	
A1 Incisor	Incisal tip of the upper incisor.	
AR – Incisor	Root tip of the upper incisor.	
A3 -- Cuspid	Tip of the upper canine.	
ANS – Maxilla	Tip of the anterior nasal spine.	
B1 – Incisor	Incisal tip of the lower incisor.	
BR – Incisor	Root tip of the lower incisor.	
B3 – Cuspid	Tip of the lower canine.	
Ba – Basion	Most inferior posterior point on the occipital bone.	
LL – Lip	Most anterior point on the lower lip (point closest to the esthetic plane).	
Me – Menton	A point located at the lowest point on the midline curve of the symphysis.	
N – Nasion	A point at the anterior limit of the nasofrontal suture.	

O – Orbitale	A point located at the lowest point on the external border of the orbital cavity, tangent to the Frankfort plane.
PNS – Maxilla	Tip of the posterior nasal spine.
Pr – Porion	A point located at the most superior point of the external auditory meatus, tangent to the Frankfort plane.
S – Sella	The center of the sella turcica, selected by inspection.
Pt – Pterygoid Point	Intersection of inferior border of foramen rotundum with posterior wall of pterygo-maxillary fossa as viewed in lateral head film, (Pterygoid Plate).
Pm – Supra Pogonion	Point selected at the anterior border of the symphysis between point B and Pogonion where the curvature changes from concave to convex.

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FRONTAL TRACING (CEPHALOMETRIC POINTS)

FRONTAL CEPHALOMETRIC ANALYSIS POINTS

① *A3 - Cuspid / ② 3A — Tips of upper permanent canines. (left) (right)

③ A6 - Molar / ④ 6A — Bilateral points on frontal occlusal plane perpendicular to buccal surfaces of the crowns of the upper first permanent molars. A6 - left. 6A - right.

⑤ AG - Mandible / ⑥ GA — Points at lateral inferior margin of the antigonial protuberances. AG- left. GA - right.

⑦ B3 - Cuspid / ⑧ 3B — Tips of lower permanent canines. (left) (right)

⑨ B6 - Molar / ⑩ 6B — Bilateral points on the occlusal plane perpendicular to buccal surfaces of the crowns of the lower first permanent molars. B6 - left. 6B - right.

⑪ JL - Maxilla / ⑫ JR — Bilateral points on the jugal process at the intersection of the outline of tuberosity and zygomatic buttress. JL - left. JR - right.

⑬ Me - Menton/ Mandible — Point on inferior border of symphysis directly inferior to mental protuberance and below center of trigonium mentali.

⑭ NC - Nasal / ⑮ CN — Points on the outline of the nasal cavity at the widest area in frontal perspective. NC - left. CN - right.

⑯ ZL - Zygomatic / ⑰ ZR — Zygomatic Bilateral points on the medial margin of the zygomatico-frontal suture, at the intersections of the orbits. ZL - left. ZR - right.

⑱ ZA - Zygomatic / ⑲ AZ — Zygomatic-Center of the root of the zygomatic arch, mid-points. ZA - left. AZ - right.

⑳ AN - Anterior Nasal Spine — Tip of anterior nasal spine just below the nasal cavity and above the hard palate.

㉑ 1A - Point 1A — Selected at the interdental pappilia of the upper incisors at the junction of crowns and gingiva.

㉒ 1B - Point 1B — Selected at the interdental pappilia of the lower incisors at the junction of crowns and gingiva.

*In all groups of two, the first entry indicates left, the second indicates right.

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| | MedScapes software can provide all 2D landmark identification, 2D analysis, & 2D growth predictions. Because the orthodontists wants this information for comparison to "traditional" cephalometrics.

(See section on landmark ID).

In traditional 2D analysis, all bilateral landmarks are averaged to the midline and are created at "standard" magnification due to the projective displacement of the object image (patients' |

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	head) to the X-ray film. These "errors" can be reproduced when the 3D data is converted to the "traditional" 2-D data set for comparison to "traditional" 2D normative data. The 2D normative data can be adjusted for sex, age, race, size, etc. and created into a graphical representation (template) of normative data for visual comparison.
3D analysis & 3D Normative Data	MedScape was founded on the premise to create, develop and offer 3D & 3D Stereoscopic software products to the medical and dental professions. MedScape products will give the doctor the ability to diagnose and treatment plan their patients with three-dimensionally accurate models of anatomy (face, teeth & bones). Three dimensionally accurate analysis and normative data critically depends on the accuracy of anatomical landmark location & identification. ** (See landmark ID) A 3D visual comparison to 3D normative data adjusted for size, sex, race, and age. 3D Normative Data - This data will have to be developed through University research as this information is limited at this time. Grayson's arcticle in the AJO describes some 3-D growth patterns. Also Rick Jacobson gives some 3-D data in Jacobson's Book "Radiographic Cepahlometrics". At this time, 3D analysis will have to be "projected" to a 2D format to compare to "narrative 2D data" since this is what exist at this time. These is some work being done in Australia and Canada on 3D MRI & Ceph data. 3D Analysis of Patient Data - The traditional 2D landmarks, angles, planes, etc. can be viewed on the 3D model for

	comparison. The 3D model will add the advantage of being able to view asymmetries of the right & left side of the face, teeth, and skeletal structure. This is a critical area that is not assessed in "traditional" 2D analyses. ** (See Highlight Abnormal) Centric Relation & centric occlusion will also be viewed in 3D. ** (See CR) ** see segment landmarks ** see convert to CR ** see meas. of soft tissue ** see fuse w/ ceph ** see output from photos ** see landmark tracking over time ** see compute angles ** see compute distances The lingual concavity of the upper and lower incisors are related to the disclusion angle and the angle of the eminence. These should be congruent w/ each other. These functional components of TMJ function and dysfunction are important concepts that are critical for proper diagnosis. 3D analysis includes modeling of the critical anatomical areas & for the generic wireframes to adjust to overlay the patient's anatomy. A visual representation of "normal" can be overlayed over the patient's "abnormal" for direct comparison .
Custom Analysis	The doctor will want to customize their analyses to include parts of various 2D & 3D analyses. The doctor can define which components of each to include. MedScape will allow the enduser to define, name, save and employ a custom analysis. This analysis can be implemented as a macro function.
Growth Forecasting	Growth forecasting has always been a goal of cephalometric

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	diagnosis and treatment planning since the early days. It became popular with Ricketts introduction to RMDS growth forecasts. 2D growth forecasting has had limited value. Short term forecasting has been acceptable at times, but long term forecasting has been inaccurate. Rocky Mountain Data Systems (RMDS) in association w/ Dr. Bob Ricketts have the most extensive data base on 2D growth forecasting. Lyle Johnston has developed a template that estimates "normal" growth "averages" in children. Also the Burlington Growth Study is also available along with the Broadbent/Bolton study, Michigan study, & others. All of these are 2D. 3D growth forecasting is yet to be developed and will be a critical area of study and development. ** see highlight abnormal ** see seg. Landmarks ** see landmark tracking over time
Visual Treatment Objective & Surgical Treatment Objective	** see segment landmark groups A visual representation of a treatment plan that a Dr. decides from using study models of the teeth, X-rays (Ceph, Frontal, Pan, etc.), and photographs of the face & teeth. The integration of the 2D ceph with 2D video imaging is now "state of the art". Some attempts have been made to have soft tissue change in relation to changes made to the bones & tooth movements, but are only in 2D (video-ceph integration). A more important treatment planning tool would be to evaluate the soft tissue changes the Dr. & patient desires (in 3D) and see

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	what changes NEED to occur in the teeth and skeletal structure to accomplish this soft tissue change. ** see also VTO (implants) STO - is a Surgical Treatment Objective This would be a surgical simulation of the movements of the bones and soft tissue to accomplish what orthodontics alone cannot achieve. ** see also Surgical planning (implants)

Orthodontic Cooperative Evaluation & Time line tracking of progress	A sequential set of photographs of the face, teeth, gingival tissues with tracking markers could allow the Dr. to track COOPERATION in areas of:
	    1. Mechanotherapy
	    2. Oral hygiene
	    3. abnormal growth
	    4. abnormal reaction to forces
	    5. other
	
	Time line tracking would allow the evaluation of progress over time. Patient's ALWAYS ask "When am I getting my braces off". Accurate 3D evaluation of cooperation and growth or surgical plans with photos would be a GREAT stride forward.
	
	Goals of Software:
	Assess Treatment Progress:
	a. Exceptional
	b. Good
	  1. On Schedule
	  2. Ahead of Schedule
	c. Fair/ behind schedule
	d. Poor/ Delayed
	
	Reasons for Progress Assessment:

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	a. Poor Co-operation
	
	     1. Head Gear
	
	     2. Elastic
	
	     3. Removable Appliance
	
	     4. Patient disinterest
	
	     5. Other
	
	b. Missed appointments
	
	c. Broken Appliances
	
	d. Lost Appliance
	
	e. Adverse Biological response
	
	f. Unexpected complexity of case
	
	g. Other
	
	Modification of treatment based on Progress assessment and reasons:
	
	a. In need of Jaw Surgery U/L both
	
	b. TMJ Surgery R/L/B
	
	c. Extraction considerations
	
	d. Parent Consult
	
	     1. Modify Treatment approach
	
	     2. Alter Fee
	
	     3. Stop Treatment
	
	     4. Other

AUTO DETECTION CEPHALOMETRIC LANDMARKS	Through automated local image analysis, the software simplifies the operator task of designating landmarks and traces. For example when tracing an intensity edge in an image, as long as the user maintains the pointer in the general vicinity of the edge, the software automatically

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	finds the edge and traces it without relying on precise pointer movement by the user.
Patient Presentation	Generic Presentation: To demonstrate possible treatment options, patient education about orthodontics using a generic patient. Custom Presentation: Demonstrate possible treatment options and outcomes using the patient's 3D anatomy. Take Home Presentation: Create a limited software program that will display a 3D model of the patient with the ability to do some minor enhancements (smile data bank). Output→floppy disc, video tape.
Arch Length Analysis and Tooth Size Discrepancy Analysis	Arch length analysis is a critical diagnostic measurement, as it can determine diagnostic decisions of extractions of permanent teeth to correct certain orthodontic problems vs. non-extractions decisions. The teeth can fit within the supporting bone (alveolar bone) to the upper and lower jaw structure. The alveolar bone is the supporting bone that surrounds the roots of the teeth. The basal bone is the main supporting structure for the jaws. The basal bone of the lower jaw (mandible) is limited in size by its genetic potential and has limited ability for growth modification. There are possible growth modifications procedures, such as Functional Jaw Orthopedics that have some limited growth modification potential. The basal bone supports the alveolar bone which supports the teeth. The alveolar bone has the potential for adaptation to the positions of

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the teeth and can be modified as long as the teeth are kept within the limits of the basal bone.

The upper jaw (maxilla) has the capability of increasing its transverse dimensions via "rapid Palatal Expansion" appliances. These types of orthopedic appliances not only change the alveolar bone shape and the size but can also change the dimension of the maxillary basal bone dimension due to "sutures" that exist in the upper jaw. The lower jaw does not have sutures associated with the mandibular skeletal structure.

The maxilla is therefore capable of being increased in size to allow for more room form crowded or crooked teeth to be aligned into "normal" occlusal fit.

Extraction vs. non-extraction of permanent teeth, the decision for a surgical solution (adult) vs. growth modification (child) to resolve "Arch Length" problems is a major diagnostic decision that the orthodontist and/or Oral Surgeon can make.

Extraction vs. non-extraction of decisions have traditionally been based on the space requirements of the mandible due to its inability to be changed significantly. Significant arch discrepancy in the lower arch may require extraction of selected permanent teeth to resolve the crowding problem, the orthodontist can then decide which teeth can be removed in the upper jaw, if any, to create a "normal" occlusal fit of the teeth.

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The teeth can fit into this ideal occlusion when the mandible is in a CR or CO position.

The Curve of Spee and the Curve of Wilson are three-dimensional relationships of the plane of occlusion when viewed from the lateral and frontal planes respectively. The analyses of these relationships of the teeth also are included in the decision making process of the orthodontist as far as the extraction vs. non-extraction treatment decisions. As the Curves "level" out the teeth could be positioned where there is no bone support leading to periodontal (gum) problems. Recession and/or alveolar bone loss could occur if not properly controlled mechanically.

In order for the teeth to "fit" normally at the end of treatment, the doctor can evaluate ALL 3D requirements of each arch, TMJ, bone configuration, etc. These include: 1. the sagittal dimensions (length), 2. the transverse dimension (width), and 3. The vertical dimension (height).

Dental extraction compensations can be accomplished in order to treat a case without surgery of the jaw structure. This compromised treatment, at times may be acceptable for patients who will not accept the surgical treatment alternative or for medical or other reasons are not candidates for orthognathic surgical procedures.

Tooth Size Discrepancy: The size of the individual teeth as they are positioned around the "Caternary" type curve of the arch, take upo space. The relative sizes of each tooth type (molars, bicuspids, cuspids, incisors) can be interrelated appropriately or the occlusion of the teeth will not fit properly at the end of treatment. If a discrepancy exists in the relative sizes of certain teeth in the arch, then a so called "Bolton Tooth Size Discrepancy" exists. This tooth size discrepancy can also effect the fit of the occlusion between the opposing arches.

It is necessary to know the mesial/distal, buccal/lingual, height measurement, along with the root lengths of the individual teeth. The root length related to biomechanical tooth movement considerations.

Bolton tooth size discrepancies are created when there is a mismatch in the size of teeth within the respective arch. This creates a problem of alignment and proper fit of the occlusion. Knowing these discrepancies prior to treatment is critical for orthodontic diagnosis. Limitations in treatment need to be related to the patient as apart of their informed consent. Small lateral incisors, abnormal shape & form, congenital absence are a few problems that create a compromised end result. Restorative dental procedures to correct some of these discrepancies, need to be planned prior to treatment so the patient will be informed and expect follow up care.

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Relapse of teeth after orthodontic correction is a major

consideration in orthodontic therapy. Many elaborate treatment

alternative have been devised to control relapse. The ability to

three-dimensionally diagnose and treatment plan a patient may

lead to improved retention of orthodontically treated cases.

Level of the Curve of Spee: The Curve of Spee is a curve of the

occlusal plane as seen from the lateral view. The Curve of

Wilson is the curve or construction of the occlusal plane as

view from the frontal. The treatment of these two "curves" are

important as to the eventual final result of the occlusion.

Orthodontist usually "flatten" these curves during treatment for

occlusal correction. Uprighting the Curve of Wilson can lead

to increased arch length and help to gain space for crowded

teeth, up to the limit of the alveolar bone, cortical bone, and

basal bone. Leveling the Curve of Spee is a routine orthodontic

biomechanical effect of treatment. This leads to a better fit of

the occlusion when the Curve of Spee is leveled. This curve

tends to deepen slightly with age, so orthodontists routinely

"over correct" the leveling of this curve to a level occlusal plane

three-dimensionally. The mathematical relationship exists to a

flatten Curve of Spee. This flattening determines the incisal

edges of the anterior teeth at one end of the arch and the disto-

buccal scups tips of the lower second molars on the other end of

the arch. By using the X,Y and Z coordinates of the occlusal

surfaces of the teeth, a calculation of the arch circumference

can be determined. The distance between any 2 points, A

	(x_1, y_1, z_1) & $B(x_2, Y_2, Z_2)$ in space is the magnitude of the vectors connecting them and is give by: $$AB = \quad (X_2-X_1)^2 + (Y_2-Y_1)^2 + (Z_2-Z_1)^2$$ Each tooth coordinate measurement represents a point in space. The total arch circumference is the magnitude of the summation of all vectors connecting their points and given by: $$C_t = \quad (X_i-X_j)^2 + (Y_i-Y_j)^2 + (Z_i-Z_j)^2$$ C_t represents the total arch circumference in 3D space and N is the number of teeth measured. To compare to 2D relationships, the planer projection of the total arch circumference is calculated using a similar method except the depth coordinate (Z_i) i.e., depth of Spee is excluded. $$C_p = \quad (X_i-X_j)^2 + (Y_i-Y_j)^2$$ C_p represents the planer projection of the total arch circumference to a lateral 2D projected view.
Asymmetry Analysis	An asymmetry analysis defines the morphology differences between the right and left halves the mandible, maxilla and other regions of the skeleton. The symmetry of these structures should be determined through the use of landmark groupings. The procedure may include determination of the sagittal plane midline of the patient by utilizing identifying midline landmarks. The sagittal plane midline can be used to define

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	the right and left halves of the patient.
	The simplest symmetry analysis would be begin with the superimposition of the right and left halves of the mandible utilizing the sagittal plane midline reference as the registration plane. The quantification of the asymmetry would be to compare the x,y,z differences in location of the corresponding right and left landmarks and to compare the location of these landmarks to the normal landmark location (by standard deviation). This type of analysis would allow the end user to quantify the amount of asymmetry and direct the end user to etiology of the asymmetry. For example, when the mandible is asymmetric then it is safe to assume that one side is too small or the contralateral side is too large. Comparison of the patient data with normal data would allow the clinician to determine which side was abnormal. Knowledge of the etiology of asymmetry may be critical in controlling or predicting the outcome of treatment.
	Additional analysis may include a normalization of the 3-D data to the standard ABO 2-D views and performing an analysis using existing analysis models. Tools may be created to allow the end user to create a symmetry analysis.
Fit to Stock Object	The spatially calibrated cephalometric views can be overlaid on the stock object. The stock object will be customized to fit the cephalometric data by either drag and drop of a stock object

	landmark to the corresponding ceph. landmark (edited in all available projection views) or by digitizing the landmarks on the ceph and then making the association and customization of the stock object through the IMS data base. A combination of the two customization methods can be used. In addition. non-landmark cephalometric data may also be associated with the stock objects. The non-landmark data of most interest are the ridge crests (i.e., orbital rims, rim of the nasal fossa, external borders of the mandible, etc. These same methods may be employed for other stock objects, such as, the teeth, TMJs etc.
Highlight Abnormal	The stock objects are a graphical representation of normal. These normal values for landmark location have been determined through an analysis of the landmark locations on many patients (Burlington study) and have been sorted by age and sex of the patient. Deviations from normal can be analyzed and statistically grouped as a standard deviation from normal. Through the use of the IMS data base we can define normal and the standard deviations from normal for individual landmarks and landmark groupings. Following the completion of the customization of the calibrated cephalometric projections to the stock object the IMS data base will perform an assessment of landmarks locations and groupings of landmarks by compare the patient data to normal data through look up tables (LUT) contained in the IMS data base. After this analysis the computer can highlight in color on

	the customized stock object the landmarks or landmark grouping that deviate 1 or more standard deviations from normal. A color can be assigned to indicate the severity of the deviation (1,2 or 3 standard deviations). This will be a very visual method for the end user to identify the locations of the abnormal growth patterns and to convey this information to the patient or colleagues. This analysis can serve as a basis for treatment planning and save the clinician time by achieving a rapid analysis and an easy method for patient communication. No look up tables are required by the doctor.
Segment Landmark Groups	Landmarks groupings (3 or more landmarks) can be used to describe the size and location of an anatomic structure relative to the remaining structures. The segmentation of these grouping allows them to be treated as objects. These landmark groupings are used in analysis of facial growth, development, temporal monitoring of growth and development, superimposition of serially acquired data sets, growth forecasting and creating visual treatment objectives. The MedScape software can have a standard set of groupings that match existing groupings. These current landmark groupings can be extended into the 3-D domain. In addition, the ability for the end-user to define additional groupings can be available.
Convert to CR	In order to convert CO to CR requires digital images at two or more visual viewing angles for the face that has embedded tracking markers that define the 3-D spatial attitude of the

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maxilla and another set of markers that define the mandible. One set of images are obtained with the teeth in CO and another set in CR. The MedScape software will track the maxillary and mandibular markers and will compute the relative changes in their spatial location relative to each other. The location of these tracking markers can be spatially cross calibrated with the cephalometric 3-D input data. The cephalometric landmark data that describes the mandible can be segmented from the remaining data. The CO→CR tracking data will be applied to the cross calibrated cephalometric data to move the mandible to CR.

Gnathological Normal	Gnathological normal refers to the cusp fossa spatial relationships, the tooth to tooth relationships among and between the maxillary and mandibular teeth and tooth position relative to the supporting alveolar0 and basal bone. The tooth and its 3-D location and spatial orientation relative to the tooth long axis can be defined through tracking of landmarks located on the root apices or apex, cusp tip(s) or incisal edge and the mesial and distal greatest heights of contour. This specialized segmentation of teeth allows them to function as objects. A database that represents gnathological normal teeth can and be used when rendering the stock object teeth in combination with the skeleton. Deviations from the gnathological normal can be described in a similar fashion to the method used for cephalometric analysis. A pseudo-colored visual display of the anatomy that falls outside the statistical normal will facilitate a quick identification of abnormal tooth position, etc.
Airway Analysis	The airway can be divided into the nasal airway, the nasal pharynx and oropharynx. The nasal airway begins at the anterior opening of the nasal passage and ends at the posterior margin of the nasal fossa. The nasopharynx begins at the posterior margin of the nasal fossa and ends at the most inferior area of the soft palate. The oropharynx begins at the inferior margin of the soft palate and ends at the superior margin of the valecula. An airway analysis includes a mathematical description of nasal septum symmetry about the

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	midline, size of the inferior turbinates, anteroposterior dimensions of the oral and nasal pharynx. The presence of adenoids, pharyngeal tonsils, tongue volume, soft palate length, and curvature of the air way.

Photographs for Cephalometric Module	
Fuse with Ceph.	A fusion of 3-D cephalometric and 3-D facial soft tissue data in the same data base will be available. This fusion will provide the ability to analyze and visualize the spatial relationships of the soft tissues and the hard tissues. The fusion will occur in the IMS data base .
Measure Soft Tissue	Selected features within the soft tissue data base can be measured. This would include soft tissues thickness and point to point surface measurement. The thickness of the soft tissue is the distance from the skin surface to the nearest point on the surface of the skeleton. The soft tissue thickness overlying the surface skeletal landmarks can be measured. In addition, other landmarks (to be determined) that define the critical soft tissue elements that are modified as a result of aging, normal growth and development, orthodontic treatment and orthognathic surgery. A special data base can be created in the IMS to sequester the soft tissue thickness data for future analysis and to determine the normal and abnormal soft tissue features and their dynamic relationships to the subjacent skeleton.

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Output of Formatted Photos	The ABO has a standard for intra and extra oral photographs. The IMS can satisfy the ABO format. Because of the data base the formatted photographs can be identified through the data base. For example, in the 8 up series, the upper left photograph is a lateral view of the head, the upper center view is a frontal view of the face and the upper right view is a frontal smile view of the face. The data base can identify the content of mount by when a standard mount format is used. This would allow the end user to search the data base and retrieve images by their attributes. For example, the end user may request that all lateral face photographs be retrieved and displayed in order by date extending from right to left. The mounted images can be output to any standard print device supported by MS Windows 95, such as a dye sublimation printer.
Landmark Tracking over Time	Knowledge of the amount of change in landmark location over time is critical when determining normal growth and development and treatment outcomes. Analysis of a change in position of the landmarks over time requires that pre-selected landmarks or landmark groupings be segmented from the remaining landmarks for an independent analysis. For example, to determine the changes that occurred in the mandible over time requires that the landmarks used to describe the mandible are segmented from the other landmarks (maxilla, etc.) and that mandible at time A is superimposed over the mandible at time B. The superimposition occurs in 3-D and the registration of the Time A and B mandibles can be

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	defined. The two mandibles may can be superimposed over a mathematically constructed sagittal plane midline, or the mandibular canals or the inferior borders of the mandible or the condyles, etc. The quantification of change will occur through the 3-D tracking of the location of the associated landmarks on mandible A and B. These differences will be tracked and recorded in the IMS data base. This IMS database can be used to assist in developing 3-D normative data.

BNSDOCID: <WO___9959106A1_I_>

Appendix F

The following describes alternative embodiments of the invention.

The problems:

Accurate 3 dimensional models are not available to all segments of medicine and dentistry because preferred image acquisition tools may not provide data in a format that is easily converted to 3D. When considering 3D techniques the data density is so great that it requires special platforms for data handling and complex algorithms for data reduction. User interface, etc.

Summary: Three basic imaging software modules (Sculptor, Clinician and Executor) comprise the Acuscape suite of software designed for the medical use. These software packages are further customized with application specific software to provide benefit to specific medical and dental disciplines. In combination these three software packages and associated application software produce spatially accurate 3 dimensional replicas (.pro file) of patient anatomy that allow for the extraction of clinically relevant data, .pro file manipulation, storage, measurement, modification and display for the purposes that include diagnosis, treatment planning, treatment simulation and outcomes measurements. The Sculptor is used at an image processing center (server) and passes the acquired images and measurement files (.scl files) to the Clinician user (client) for the generation of the .pro file and subsequent use.

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Sculptor Module: Images are acquired directly into a patient session file from input devices that include digital cameras, flat bed scanners, x-ray sensors, etc. or from image storage files. An **Acuscape image calibration frame** is worn during image acquisition and shadows of the calibration markers are embedded on the resultant images.

The images are first **spatially calibrated** and a patient centric co-ordinate system is transferred to the images. This co-ordinate system is adjusted or optimized to best fit the patients anatomy. Part of this adjustment superimposes the y-z plane of the co-ordinate system to superimpose on the patient's mid-sagittal plane. The subsequent measurements store data utilizing this constructed co-ordinate system. The calibrated images can be stored by the executor or displayed and measured. Multiple images or image sets can be combined in a common 3-D database, displayed at as a combined set and can be selectively enhanced for improved measurements. These enhancements include magnification and equalization of selected image regions. Three space measurements can be performed as point, closed loop trace and linear trace measurements. The measurement routine occurs simultaneous on all images displayed in the sculptor. The selected image is measured and a corresponding epipolar line is constructed on the adjacent images to assist with locating the same point on that image. The z,y and z locations of all of the measurement points and lines (series of points) are stored in a measurement file. The measurement files are converted to an export file that contains all .jpg images

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and a .scl file. The .scl files contain the calibration information, camera

parameters and the x,y and z locations of all traces and landmarks.

The sculptor facilitates the measurements on all calibrated or cross calibrated

images. Cross calibration refers to calibrating multiple images and image types

to the same 3D co-ordinate system. These images can include but are not limited

to x-rays, tomographs, CT scans, visual band images, MRI, ultrasound, infrared

and radar. The image type and projection angulation will be dictated by the

intended purpose of the imaging study. This is an application specific program

that has been optimized to facilitate the original imaging goals. The Sculptor

will be used to calibrate and measure the images (spatially, color or gray scale

value).

Executor Module: This module works in the background to manage images

for the Sculptor and Clinician modules. This is a patient centric relational data

base with multiple tables that stores, retrieves and transports patient image files.

Patient file transport files contain the .jpg images and an .scl file. The .scl file is

created by the Sculptor and transported to the Clinician by any number of means

including modem, internet and floppy, etc.

Clinician Module: The module is intended to exist primarily in the doctor's

office (end user). The Clinician will receive the transport file from the Sculptor

via the Executor. The patient specific measurements contained within the .scl

file are used by the morph editor, a sub-section of the Clinician, to morph a

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"stock model" to spatially match the patient's measurements. The "stock model" is a generic wireframe representation of the anatomy to be modeled. The measurements include specific linear traces, closed traces, landmarks and control points. The measurement locations are pre-programmed into the Sculptor and the corresponding locations are programmed to the corresponding points on the stock wire frame of the Clinician. For example, the orthodontic application includes traces of ridge crests (orbits, mandibular borders, etc.), landmarks (nasion, Sella, etc.) and control points (tooth cusp tips, etc.). These measurement locations and names associated with their precise locations on the "stock model" are contained within the Clinician's database. The Clinician's knowledge of the precise wireframe vertices associated with the locations of landmarks, traces and control points facilitates the automation of using the .scl file to morph a generic stock model to a patient specific model (.pro file).

A specific .pro file can be retrieved via the Executor and displayed, analyzed and manipulated as a solid model in the Clinician module. The .pro file will exist as a collection of anatomic "objects". These objects will include anatomic structures, such as each tooth, landmarks and reference planes. The spatial location of all objects are known and tracked by the Clinician's database. The .pro file possesses an x,y,z co-ordinate system referred to a the global co-ordinate system while each object possesses its own co-ordinate system referred to as a local co-ordinate system. The Clinician's database is monitoring the spatial location of the .pro file and its sub-objects via their co-ordinate locations. The .pro file and/or any of its objects can be translated or rotated along their co-

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ordinate axes. The movements will occur along the default global co-ordinate

system unless an object or group of objects has been selected then the movement

occurs along the selected local co-ordinate system.

The orthodontic application uses a stock model of the head and portions of

the neck. This stock model includes, but is not limited to, the associated

skeleton, soft facial soft tissues, temporomandibular joints and teeth. In the

examples shown this model currently contains more than 300 objects that can be

manipulated in the clinician module to facilitate the kinds of tasks routinely

undertaken by an orthodontist.

The Claims

What is claimed is:

1   1. An apparatus for calibrating medical images of a patient comprising:

2   a headgear for mounting to a patient's head, and

3   a plurality of calibration targets mounted on the headgear.

1   2. The apparatus of claim 1 in which the headgear is size adjustable.

1   3. The apparatus of claim 1 in which the headgear comprises a rigid portion to

2   which the plurality of calibration targets are mounted.

1   4. The apparatus of claim 3 in which the plurality of calibration targets are

2   mounted so as to reduce the amount of overlapping when an image of the

3   appartus is captured.

1   5. The apparatus of claim 1 in which the plurality of calibration targets are

2   spherical.

1   6. The apparatus of claim 1 in which the plurality of calibration targets comprise

2   at least one of BBs and bearings.

1   7. A computer apparatus comprising:

2   a computer having a processor and memory; and

3   software for execution on the processor, comprising a module for receiving

4   image data for a patient, for establishing a reference frame to relate

5   anatomic locations of the patient, and for generating a 3D patient specific

6   model from a stock model using the related anatomic locations.

1   8. The computer apparatus of claim 7 in which the module creates a data file

2   containing patient specific information for transfer to another module.

1   9. A computer apparatus comprising:

2   a computer having a processor and memory; and

3   software for execution on the processor, comprising a module for receiving

4   patient specific images and patient specific information, the software

5   having access to a generic three-dimensional model, the software for

6   customizing the generic three-dimensional model using the patient

7   specific information to form a customized three-dimensional model of at

8   least a portion of the patient's anatomy.

1   10. The apparatus of claim 9 in which location of one or more particular three-

2   dimensional model vertices is changed in accordance with the patient specific

3   information.

1   11. The apparatus of claim 10 in which the locations of other three-dimensional

2   model vertices are changed to be conform with the change in location of the

3   particular three-dimensional model vertices.

1   12. The apparatus of claim 9 in which the generic three-dimensional model

2   comprises a plurality of objects each having an individual object coordinate

3   system referenced to a model coordinate system.

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1   13. The apparatus of claim 12 in which the software further comprises a three-

2   dimensional model viewer capable of manipulating the objects individually or

3   collectively.

1   14. A method of capturing and handling medical images, the method comprising

2   the steps of:

3   mounting a calibration frame on a patient;

4   capturing images of the patient and the calibration frame from different

5   perspectives; and

6   storing images from a patient resulting from a plurality of sessions in

7   respectively separate portions of a file management system so that all

8   patient related data is available in a single entity.

1   15. A method of processing medical images comprising using corresponding

2   points on different images of a patient to establish a patient centric coordinate

3   system with respect to which a three-dimensional model is referenced.

1   16. The method of claim 15 in which the corresponding points are determined

2   using images of a calibration target.

1   17. The method of claim 16 in which images of a calibration target are

2   determined using blob analysis.

1   18. The method of claim 15 in which the corresponding points are used to

2   identify the location of a calibration target in three-dimensional space.

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1   19. The method of claim 15 further comprising the step of referencing points on

2   the medical images to the patient centric coordinate system.

1   20. The method of claim 15 further comprising the step of modifying the

2   location of particular points on the three-dimensional model to correspond to

3   patient specific information and morphing the three-dimensional model to adjust

4   the locations of other points correspondingly.

1   21. A method of analyzing patient images comprising the steps of:

2   identifying one or more anatomical locations in a plurality of patient images

3   from a particular patient imaging session;

4   determining anatomical locations information in a relative to a reference

5   frame established from the plurality of patient images; and

6   using the anatomical location information for patient treatment planning and

7   execution.

1   22. The method of claim 21 in which an anatomical location is identified by a

2   plurality of points constituting an outline trace of the a portion of the patient's

3   anatomy.

1   23. A method of identifying corresponding points in a plurality of images which

2   constitute different views of a three-dimensional space, the method comprising

3   the steps of:

4   determining a common reference frame for the plurality of images;

5   selecting one point on one image;

6   generating a line through that point;

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7   displaying a projection of the line in at least one of the other of the plurality

8   of images; and

9   using the projection of the line in at least one of the other of the plurality of

10   images to identify a corresponding point in that image.

1   24. A method of identifying the location of a point in a three-dimensional space

2   using two dimensional images which are substantially projections of a three-

3   dimensional model, comprising the steps of:

4   selecting a particular point on one of the two dimensional images;

5   selecting the same point on at least one other of the two dimensional images;

6   identifying the associated vertex on the model of the particular point on the

7   images;

8   determining the selected point location by interpolating between known

9   locations of model vertices based on interpolation using pixel count

10   between the particular point and one or more sets of adjacent vertices.

1   25. The method of claim 24 in which distance between two points is determined

2   by identifying the locations of the two points and determining line length using

3   the coordinates determined for those points.

1   26. A system for using patient image information, comprising:

2   a computer configured to customize a generic three-dimensional model using

3   patient specific information;

4   a network linking the computer to a second computer; and

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5   the second computer configured to receive the patient specific information

6   and to customize a locally stored generic three-dimensional model using

7   the patient information.

1   27. A computer program product, comprising:

2   a memory medium; and

3   a computer program stored on the memory medium, the computer program

4   comprising instructions for using corresponding points on different

5   images of a patient to establish a common reference frame, the computer

6   program further for determining the relative location of anatomical

7   locations of the anatomy of the patient using the different images and the

8   common reference frame.

1   28. A computer program product, comprising:

2   a memory medium; and

3   a computer program stored on the memory medium, the computer program

4   comprising instructions for identifying one or more anatomic location in a

5   plurality of patient images from a particular patient imaging session,

6   calculating anatomic location information in a common reference frame

7   established from the plurality of images, and using the location

8   information for patient treatment planning.
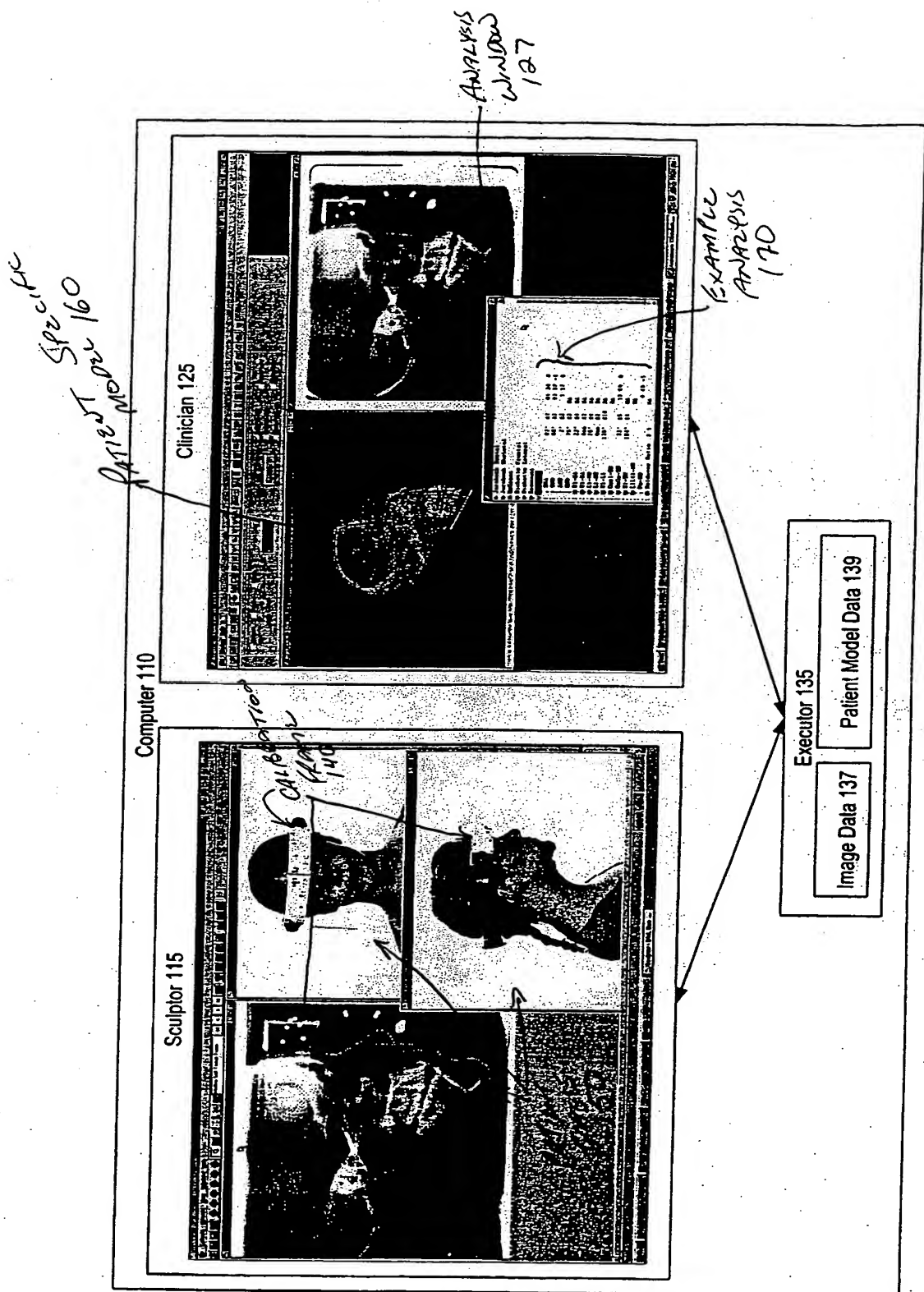
Figure 1
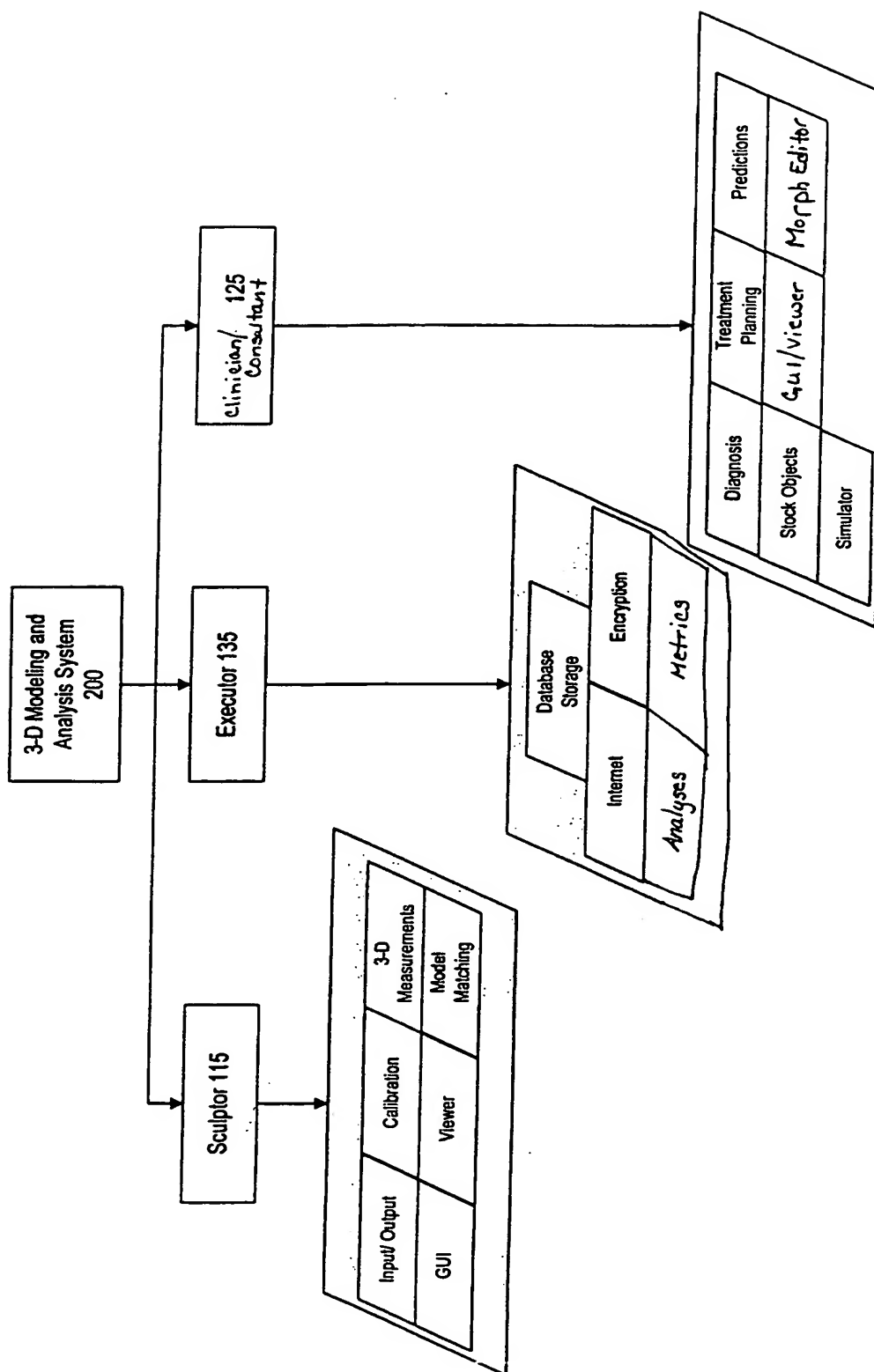
Figure 2

H \PRIVATE\CLIENT\20256 Acascape\701 3D Modeling from 2D Images\Figure 02 Architecture v13

Figure 3

Plexiglass
Frame 430

Calibration
Frame 140

ACUS APE

Calibration
Target 440

Patient 300

Top Strap 405

Strap 410

Attachment
450

Adjustment
Knob 420

Figure 4

Figure 5

Figure 6

SCULPTOR INTERFACE 715

PATIENT IMAGE 750

CALIBRATION FRAME 140

PATIENT 300

SCULPTOR TOOLBAR 720

FIGURE 7

Initial Image

SCULPTOR INTERFACE 715

UNALIGNED CALIBRATION TEMPLATE 810

CALIBRATION FRAME 140

PATIENT IMAGE 750

PATIENT 300
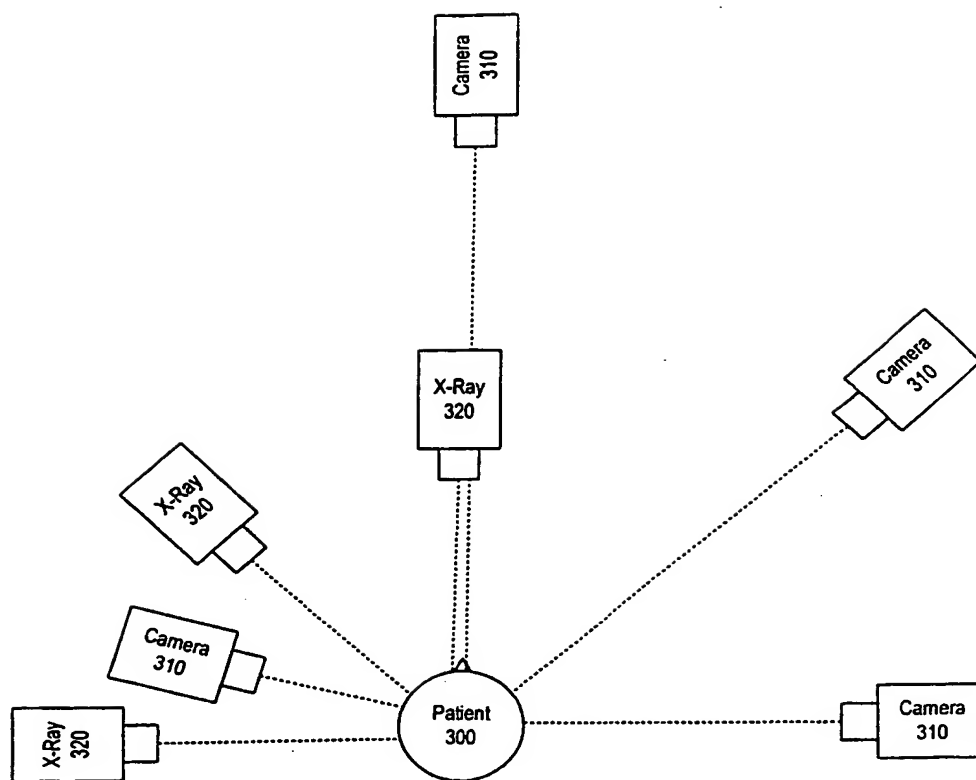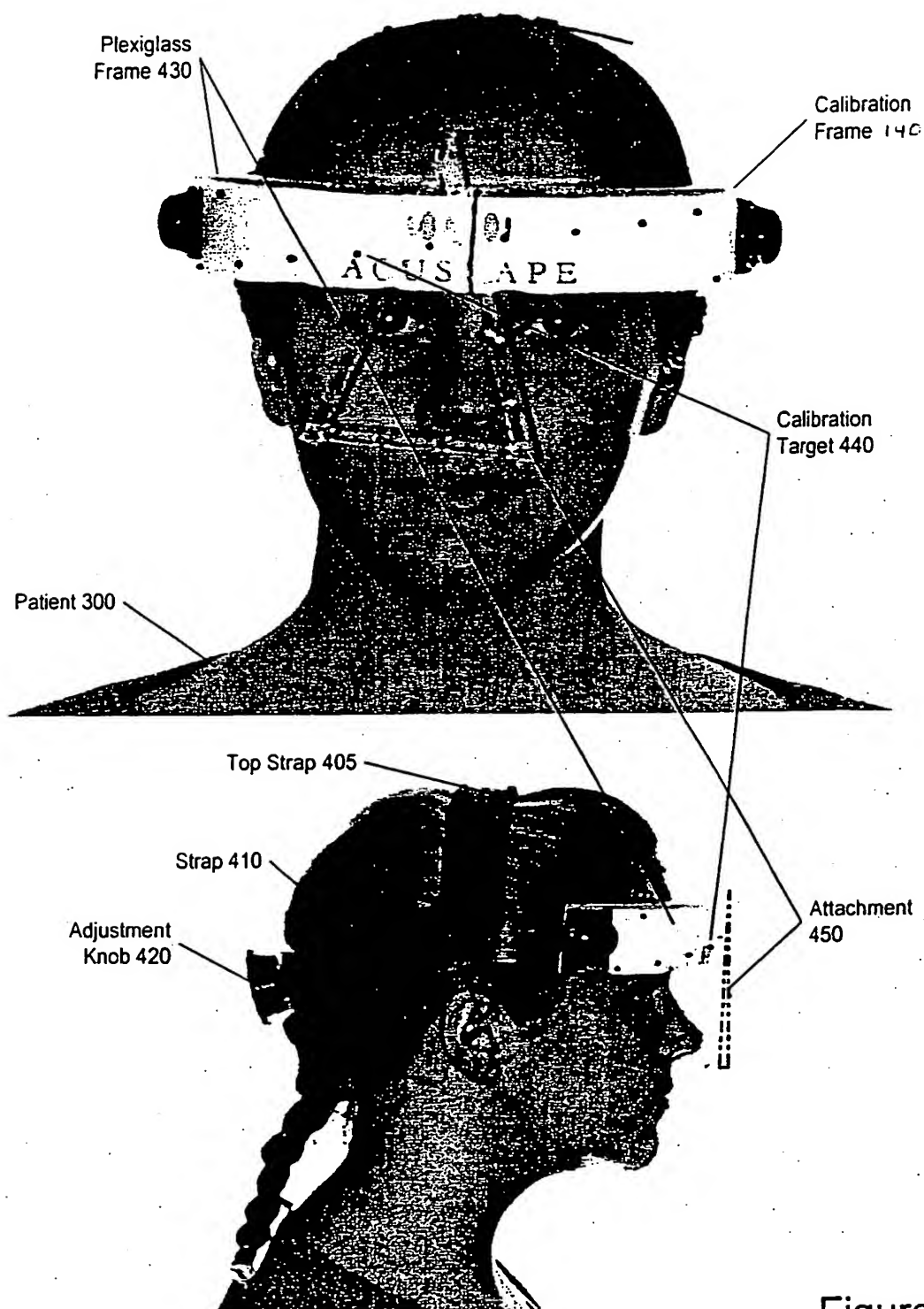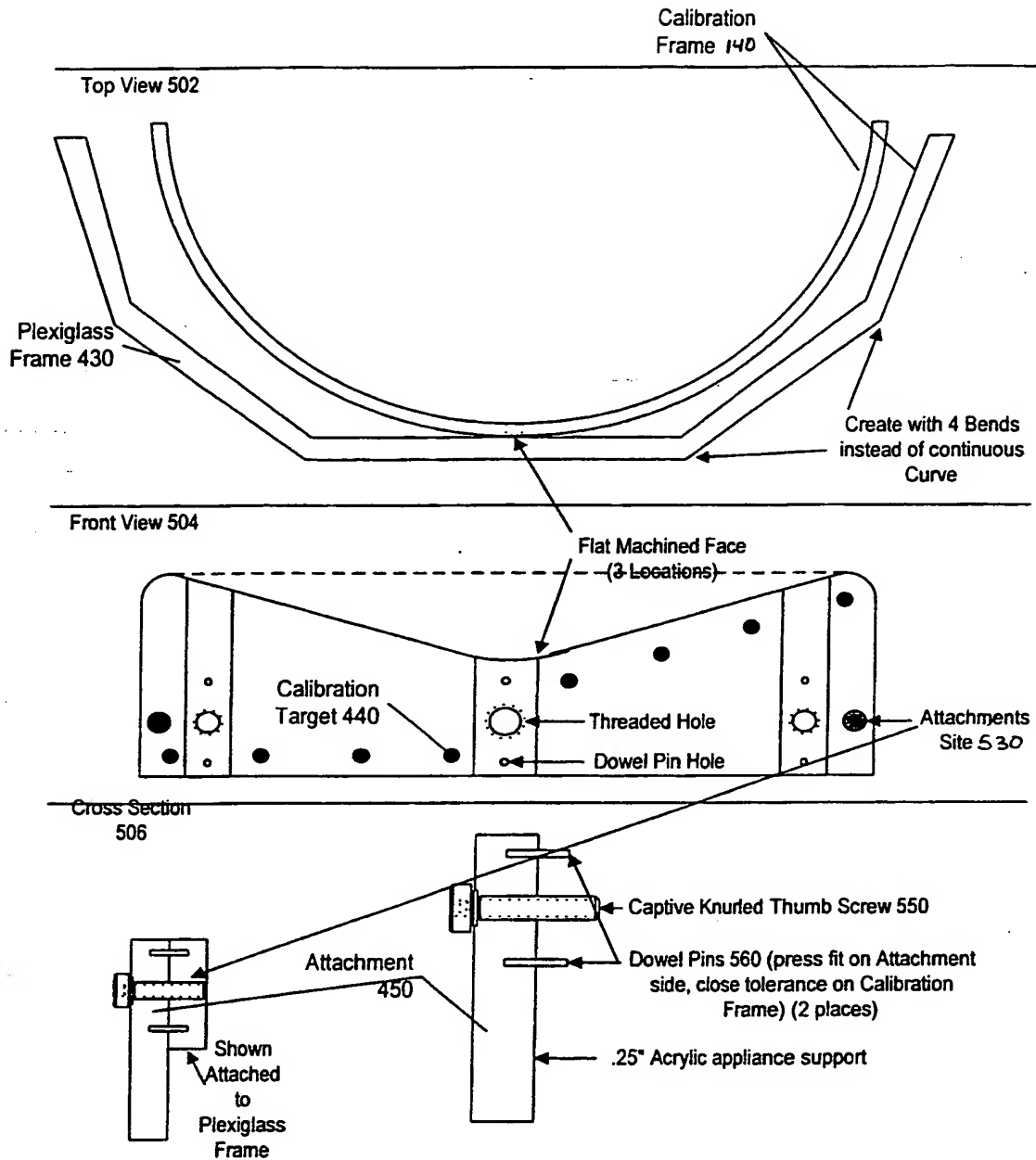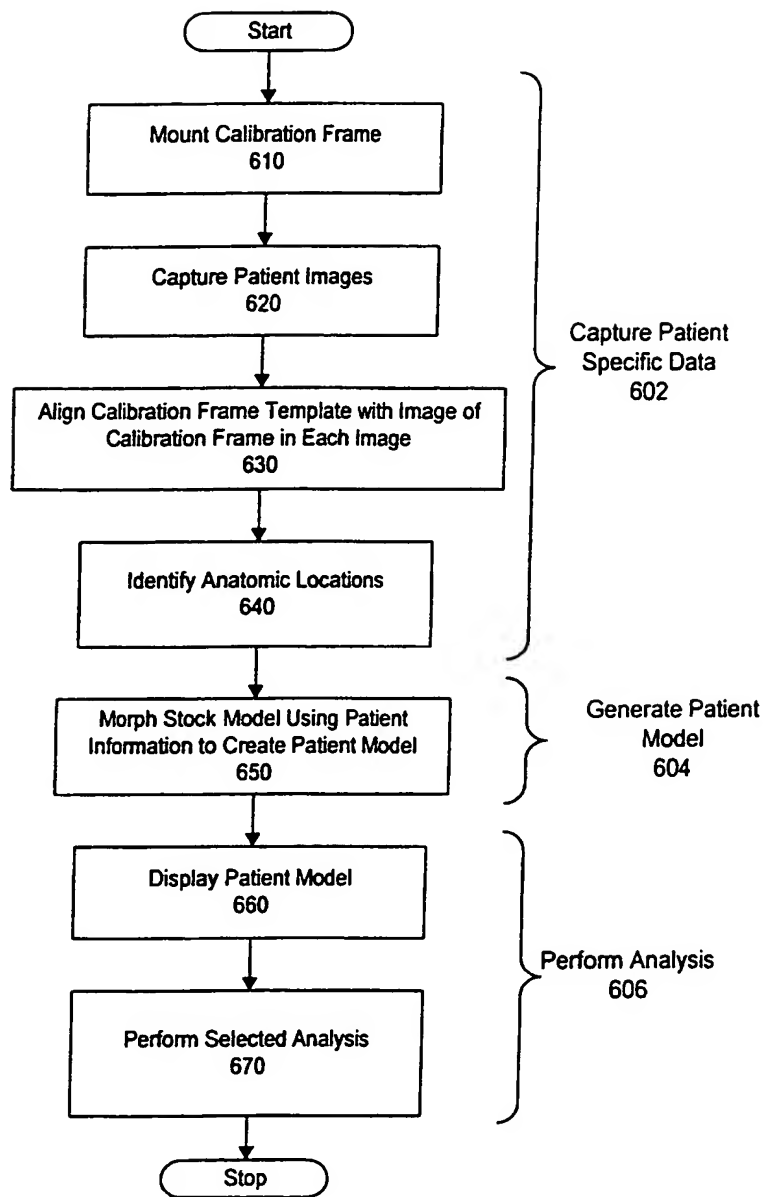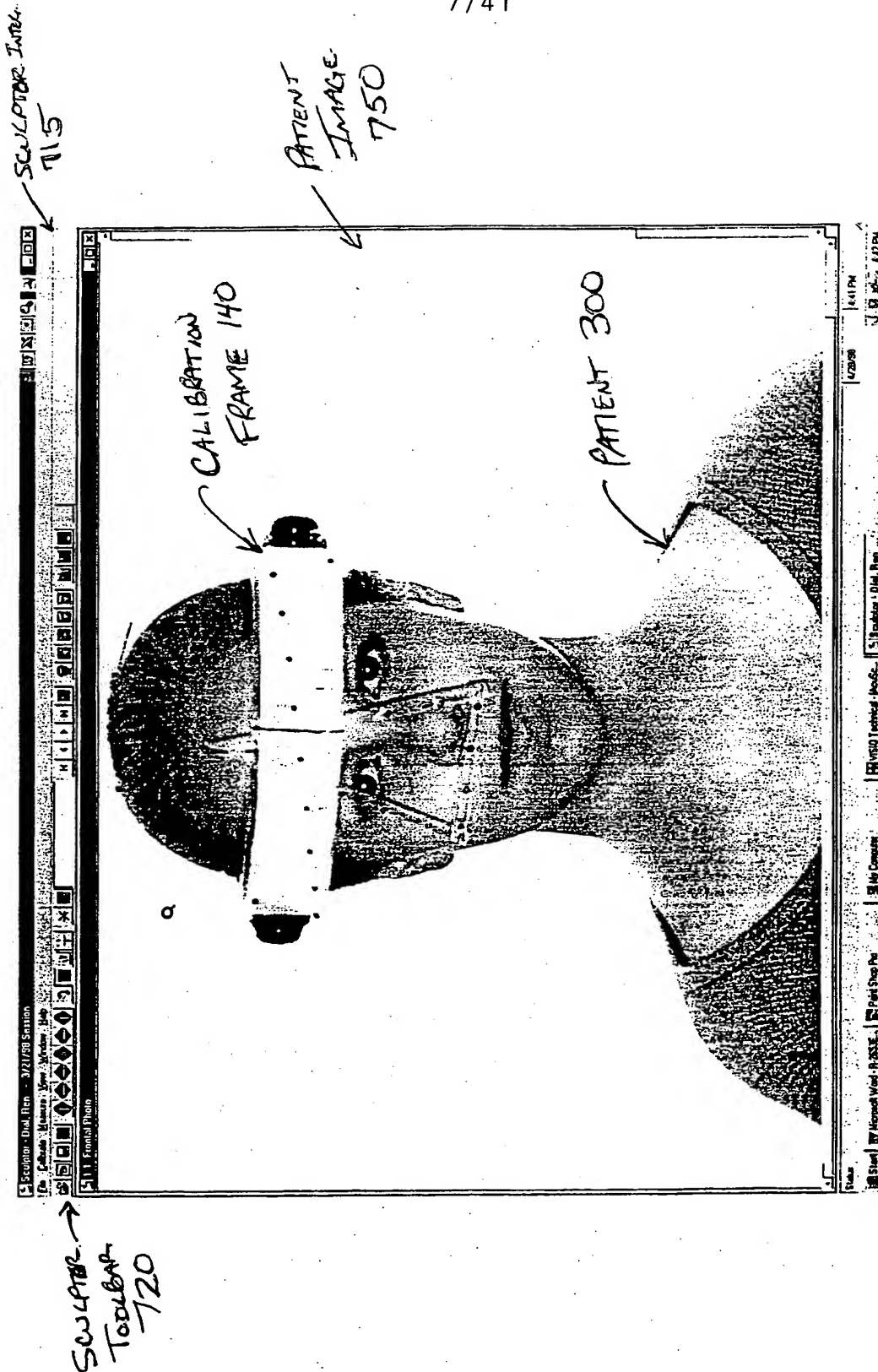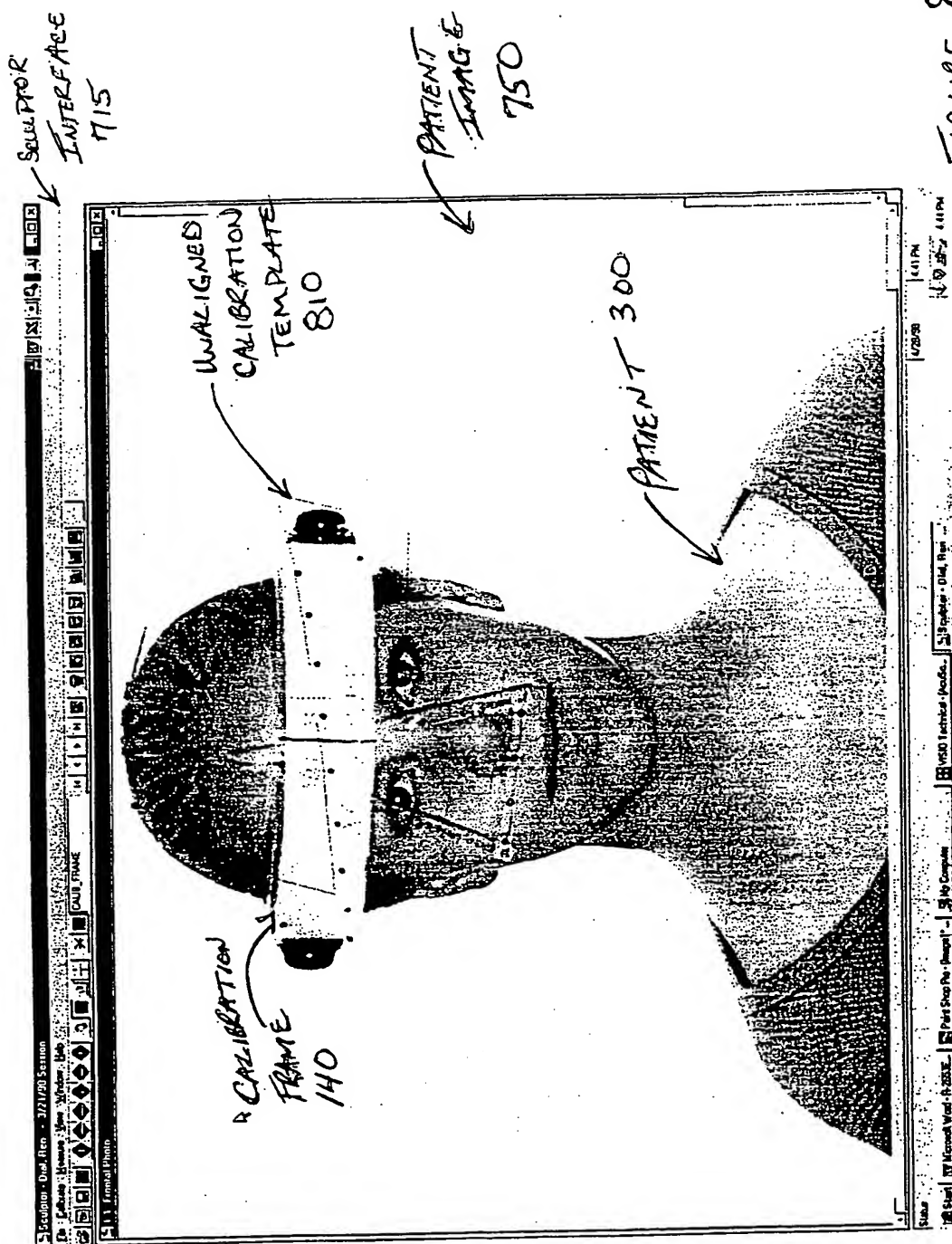
Initial Calibration Template Display

FIGURE 8

CALIBRATION TARGET SELECTOR 910
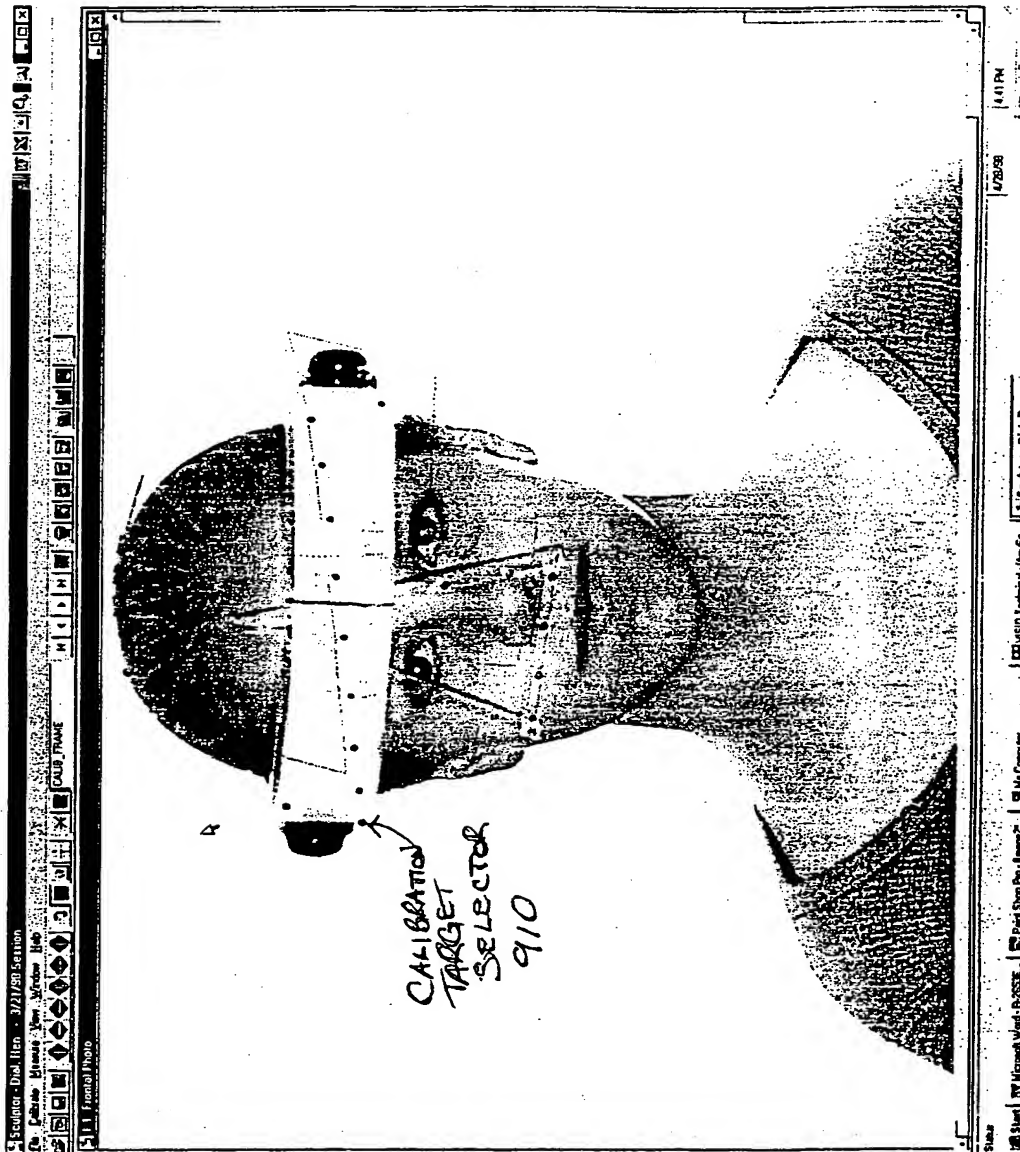
Figure 9

Partially Calibrated with 4 Calibration Targets Set

FIGURE 1C

Partially Calibrated Image

FIGURE 11

Calibration Template Set

CALIBRATION FRAMES 140

ALIGNED CALIBRATION TEMPLATE 1110

PATIENT IMAGE 1750

PATIENT 300

PATIENT 300

PATIENT IMAGE 1250
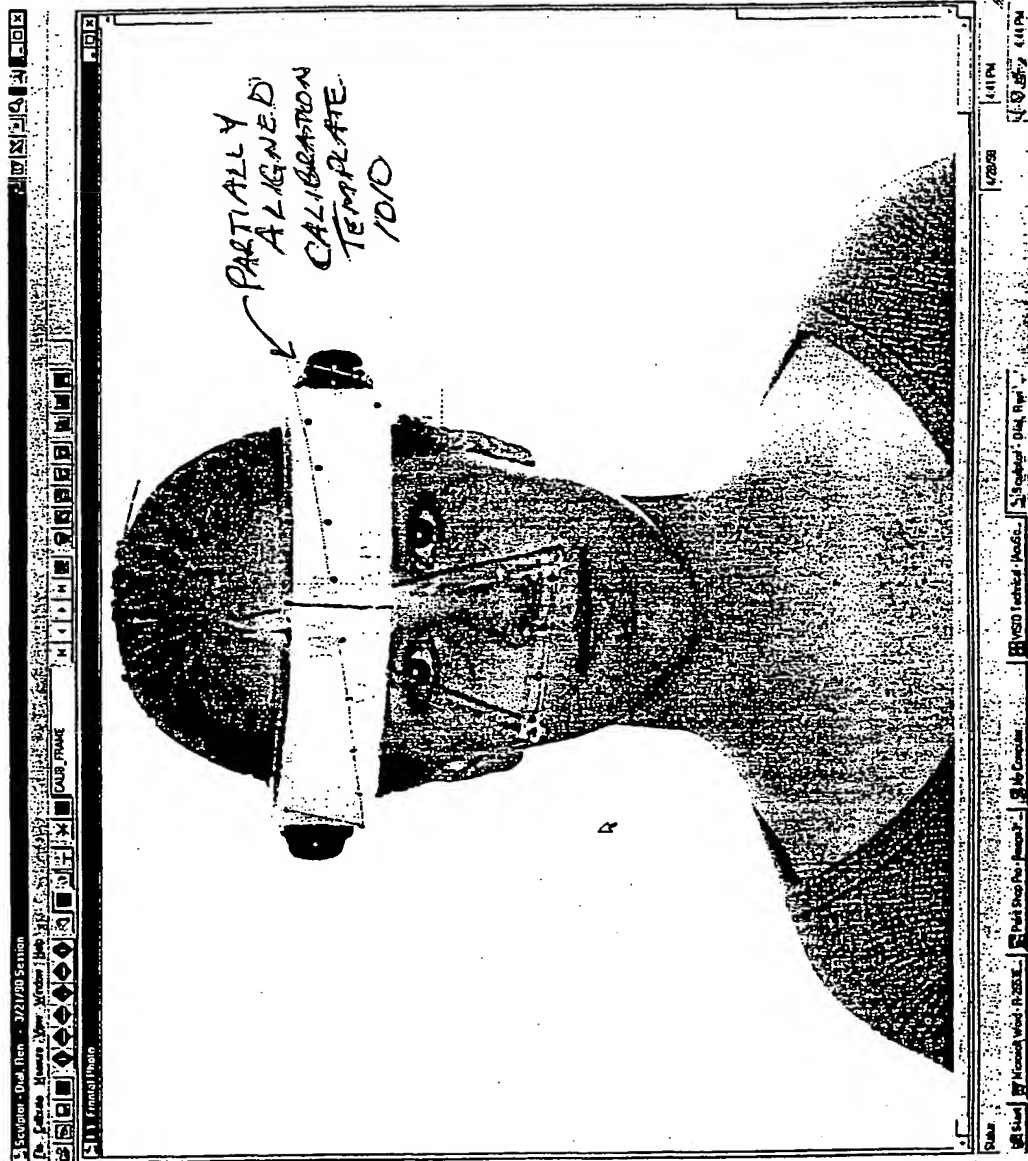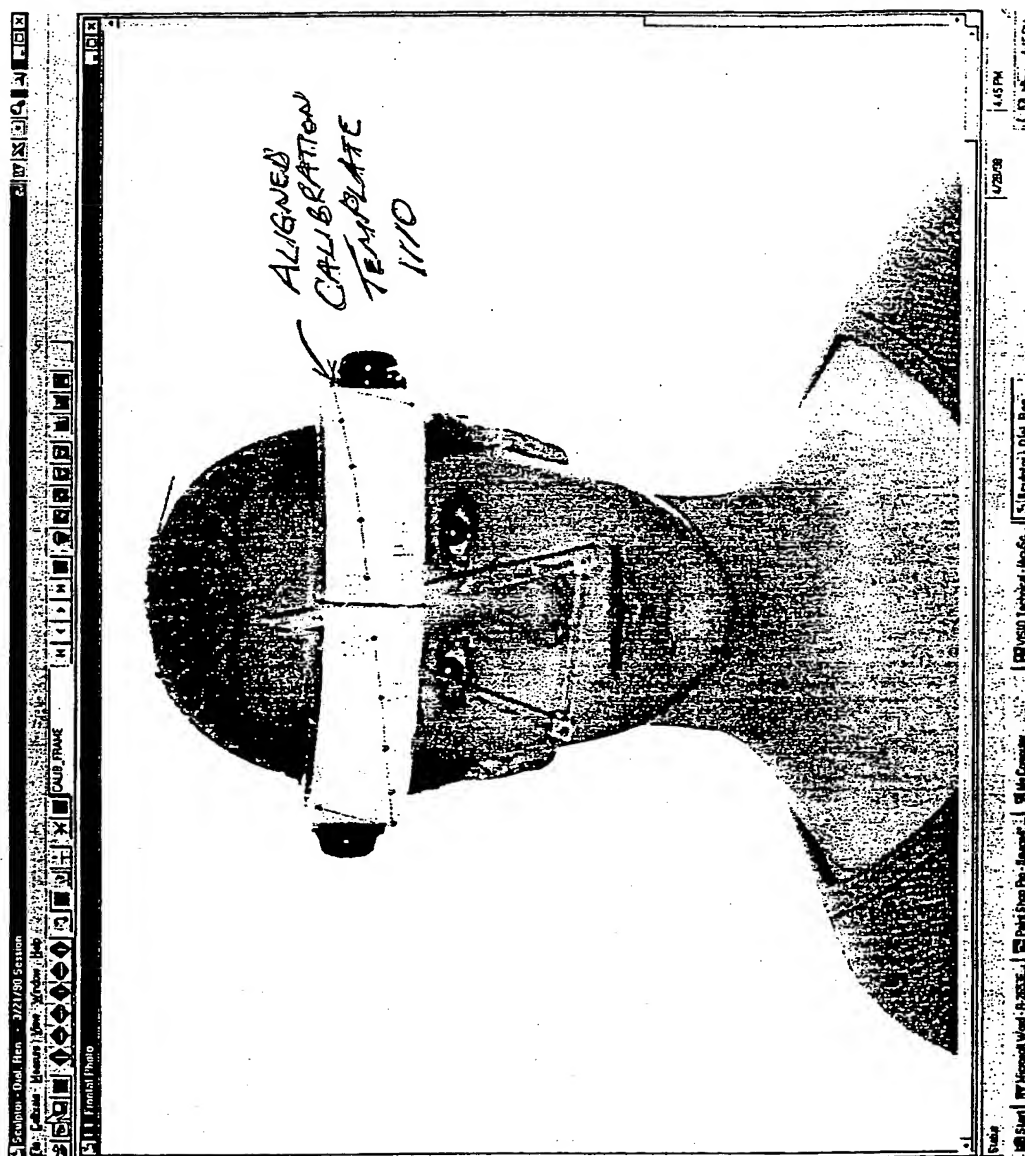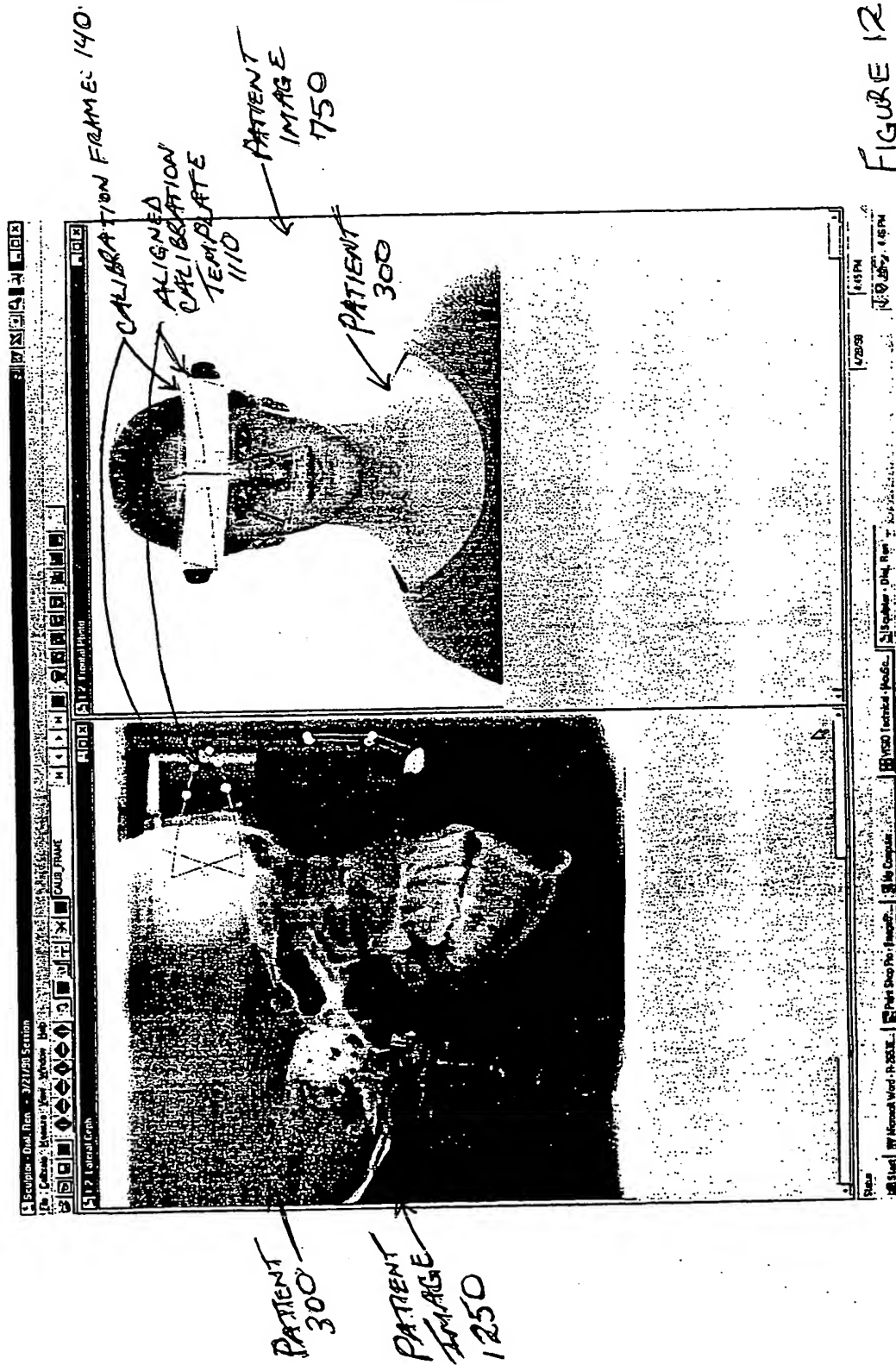
FIGURE 12

Cross Calibrated Images

FIGURE 13

Reference Plane

COORDINATE-
REFERENCE
ORIGIN
1310

TRACE NAME 1410

MIDLINE SOFT TISSUE TRACE 1410

PATIENT IMAGE 1450

FIGURE 14

Traces with no Soft Tissue Enhancement
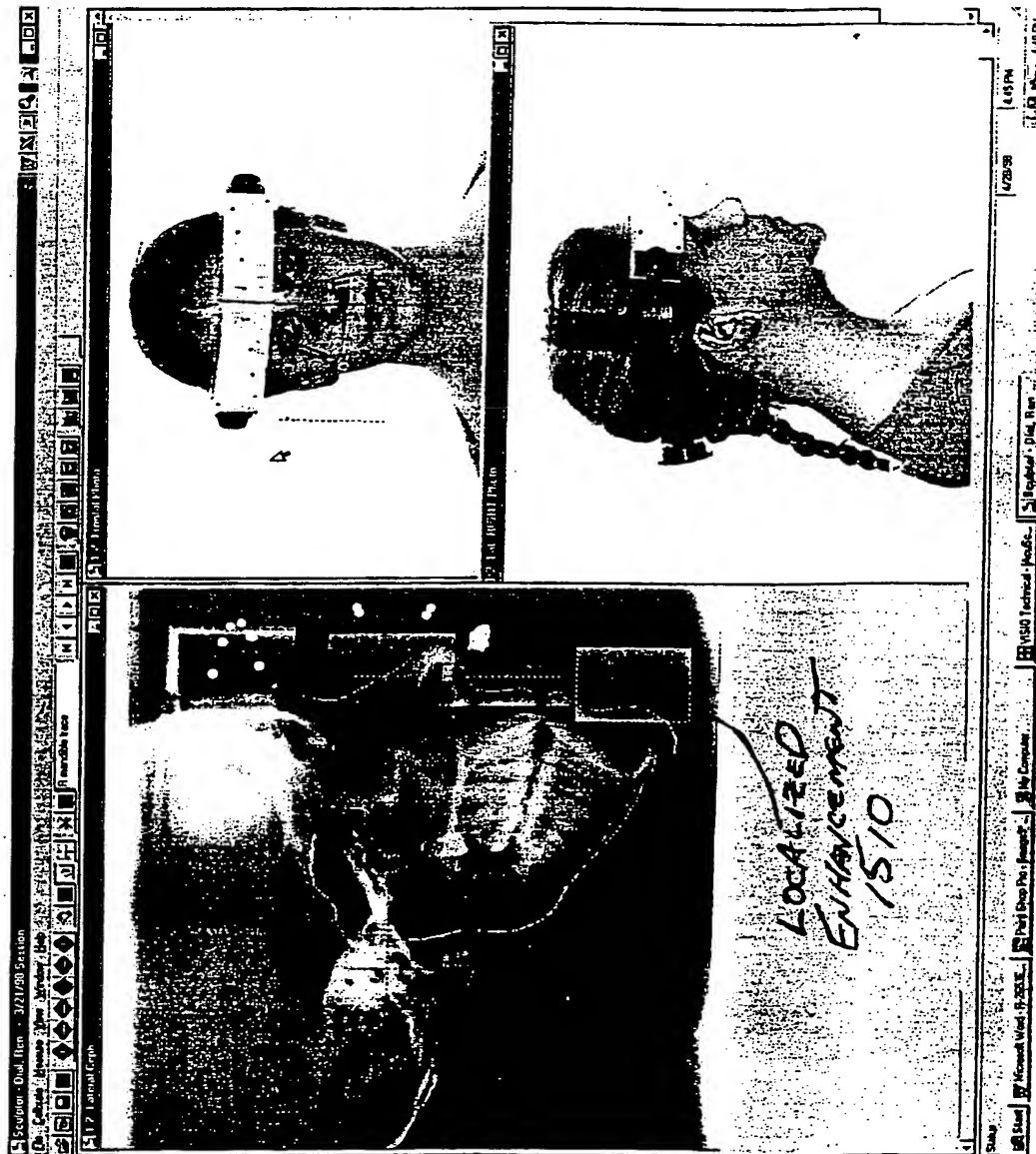
Traces in Multiple Images with Enhanced
Soft Tissue
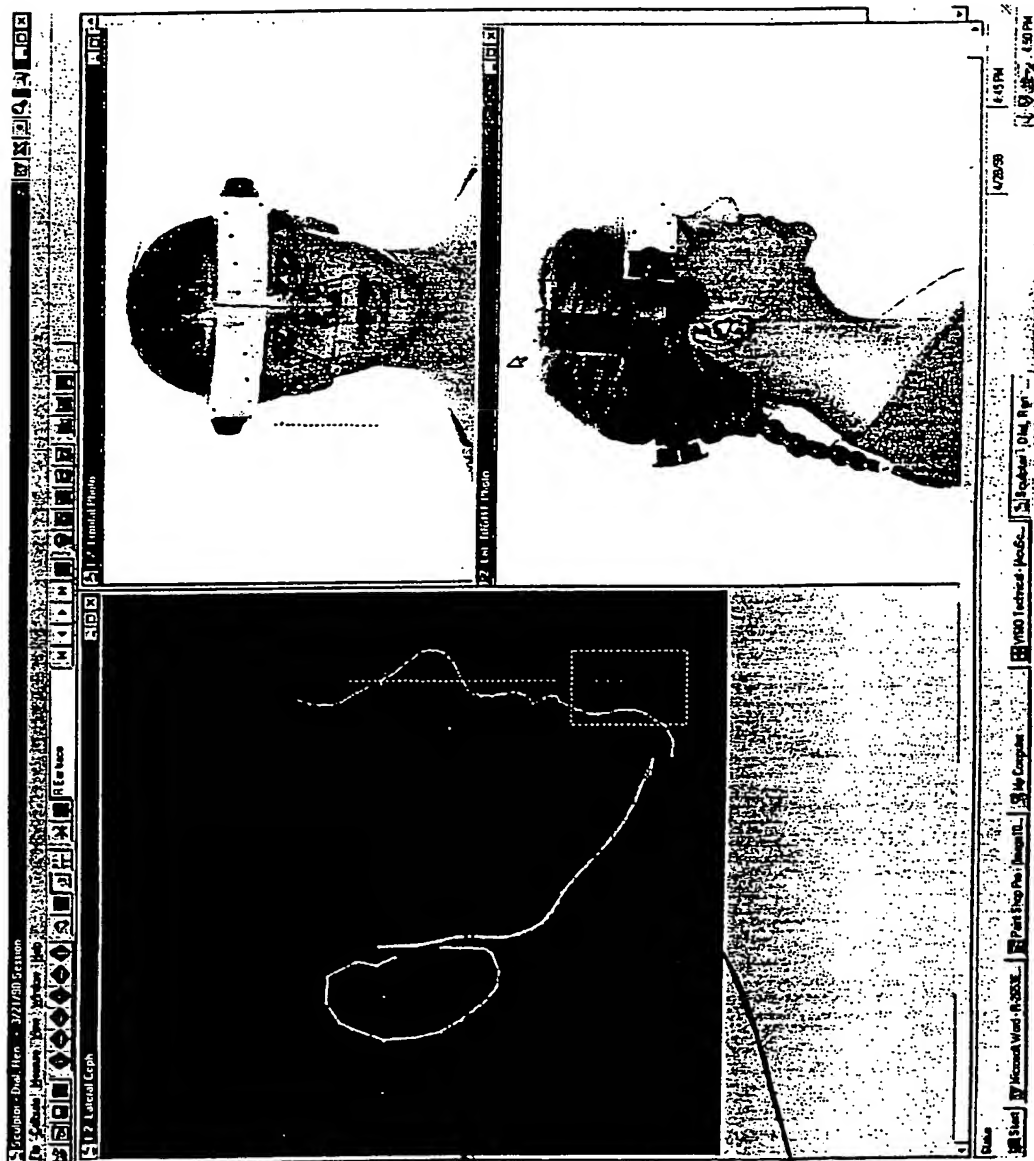
Figure 15

TRACE
+
LANDMARK
VIEW 1620

EXAMPLE
TRACE
1610

FIGURE 16

Skeleton Dropped Out From Under
Traces-Virtual View
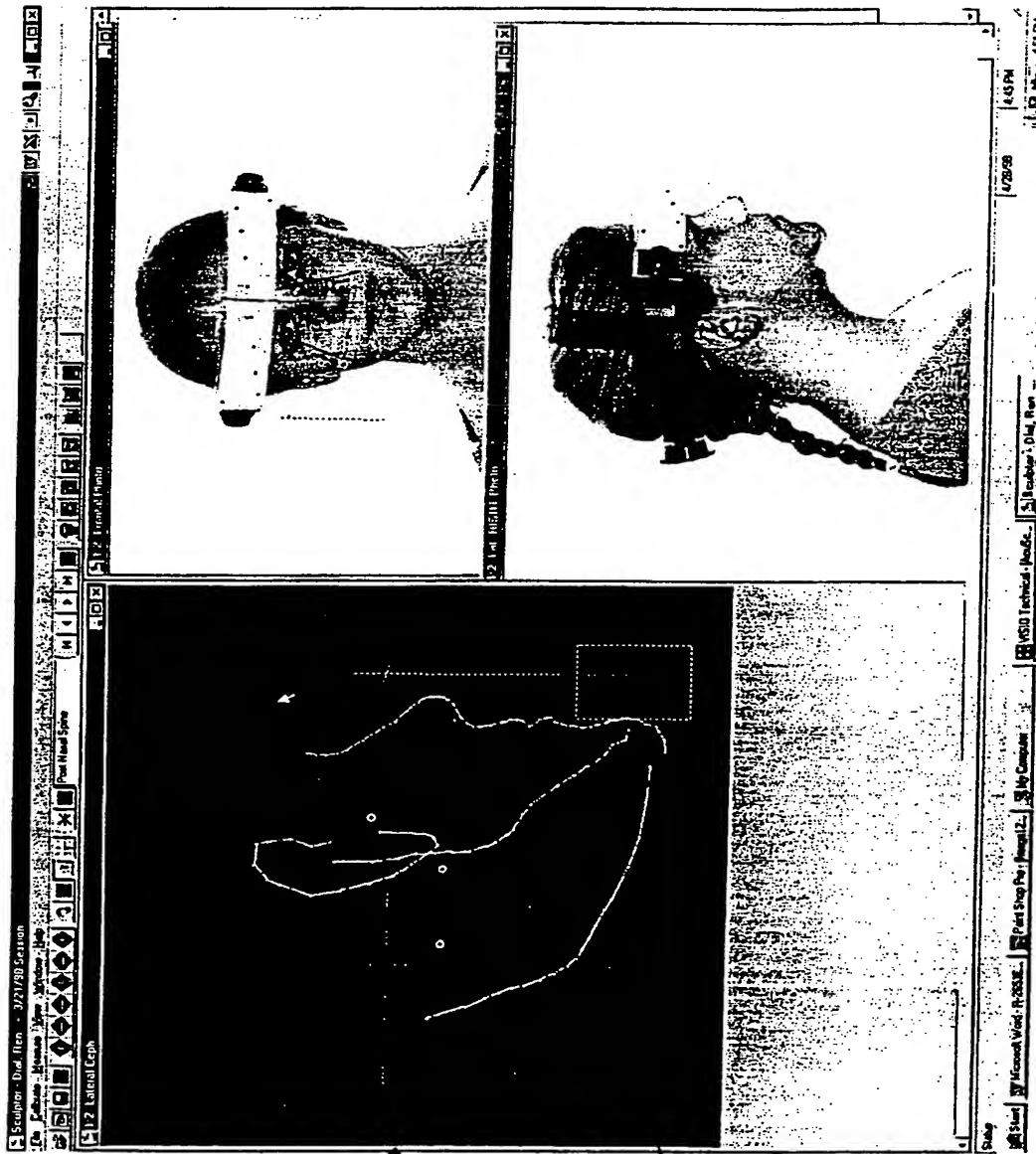
ROTATED VIEW 1720

EXAMPLE TRACE 1610

FIGURE 17

Virtual View of Traces and Landmarks

PATIENT IMAGE 1450

PATIENT IMAGE 750

PATIENT IMAGE 1850

PATIENT IMAGE 1250
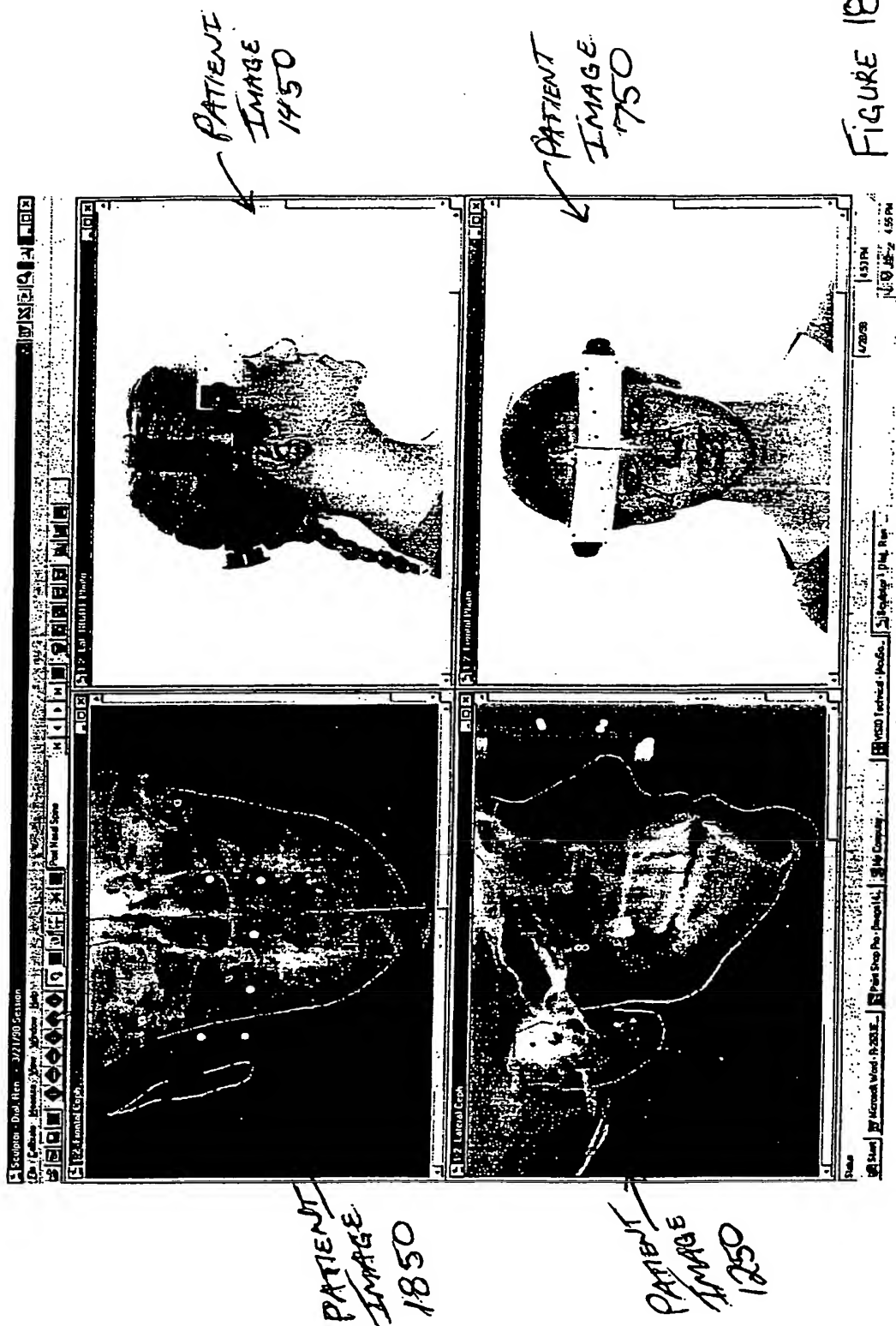
FIGURE 1E

Landmarks and Traces Displayed Multiple Images

FIGURE 19

Measure Between Bone and Soft Tissue
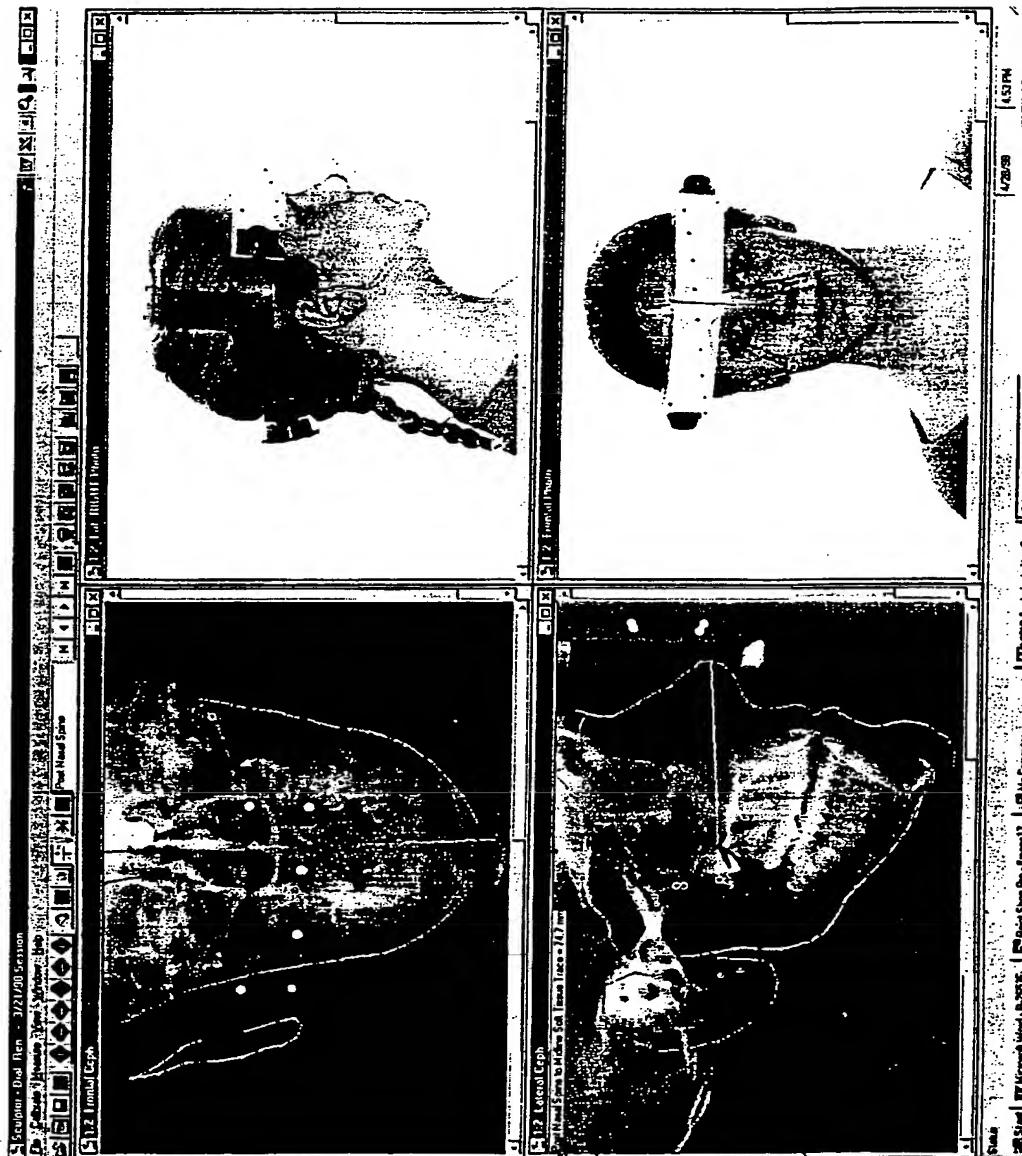
MEASUREMENT INFORMATION 1920

MEASUREMENT LINE 1910

POST NASAL SPINE LANDMARK 2010

EPIPOLAR LINES 2020

PATIENT IMAGE 2050

FIGURE 20

3 Images with Epipolar Lines, Post Nasal Spine Land

TRACE POINT 2120

RIGHT MANDIBLE TRACE 2110
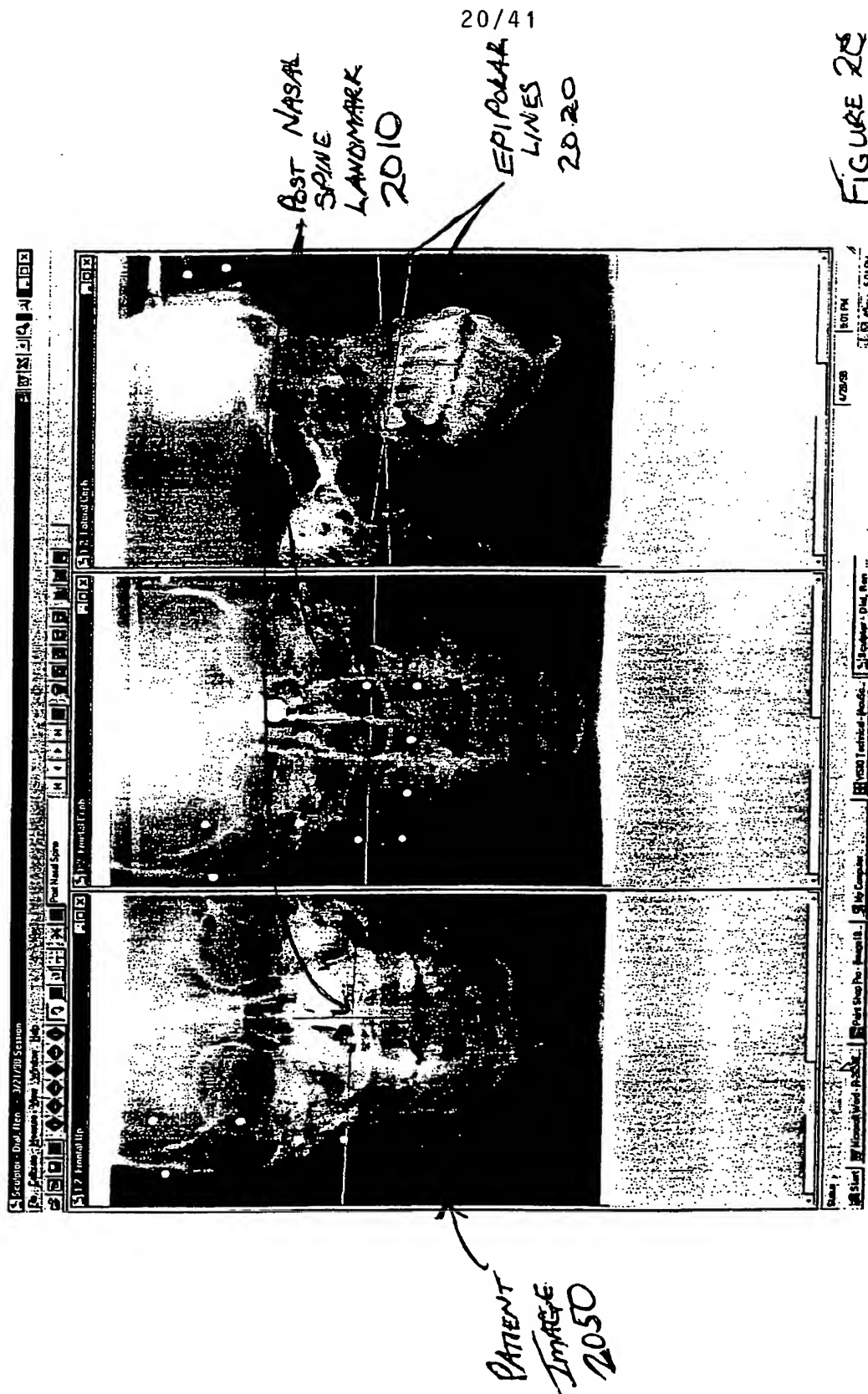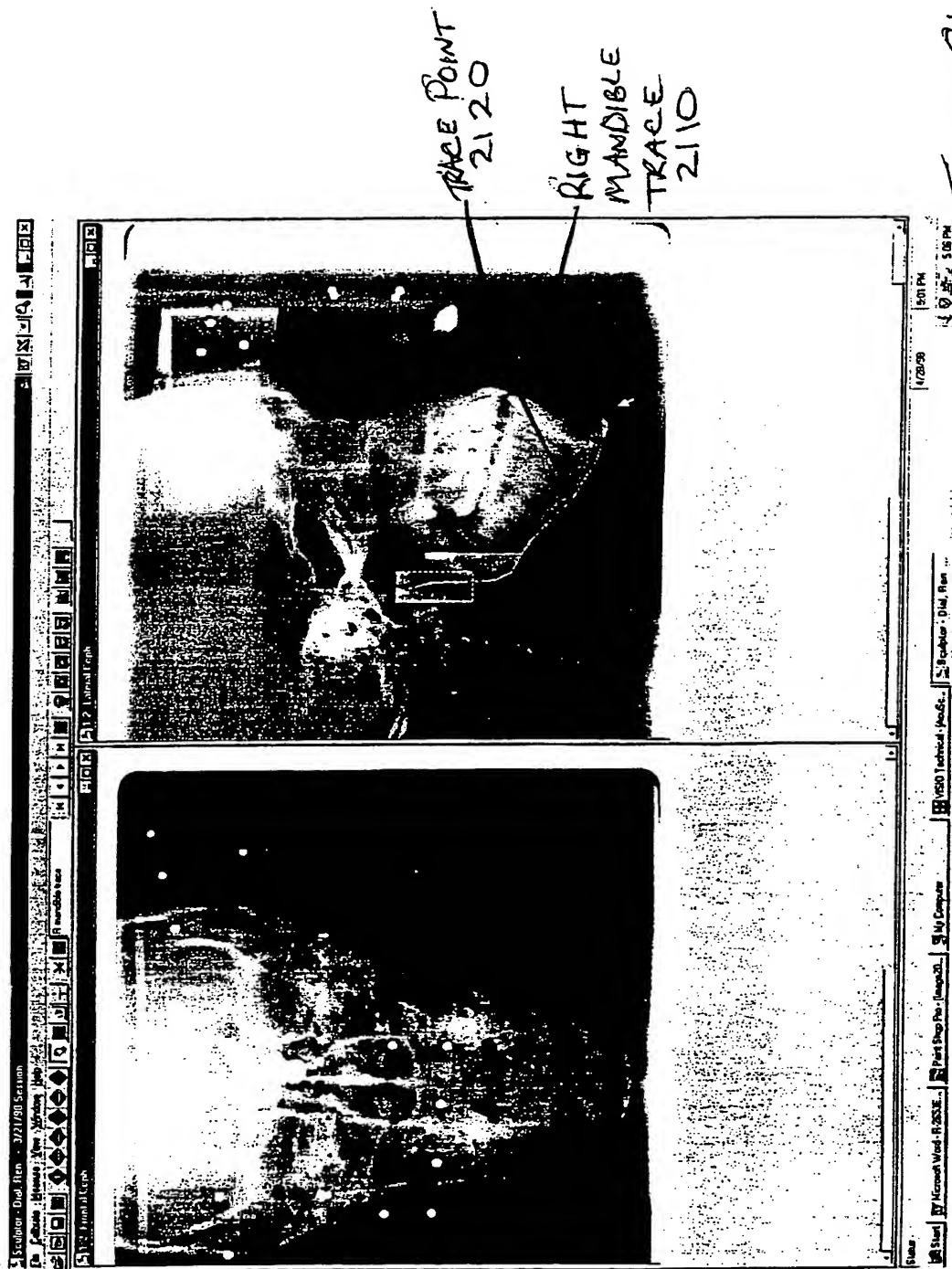
FIGURE 21

Trace Complete on one image. Start on next

Figure 22

Placing Next Point along Jaw

PATIENT IMAGE 1850

TRACE LINE 2200

TRACE POINT 2210

NEXT TRACE POINT 2220

TRACE LINE 2200

TRACE POINT 2210

NEXT TRACE POINT 2220

Next Point in trace set

FIGURE 23

3D Trace Mapped onto Untraced Image

FIGURE 24
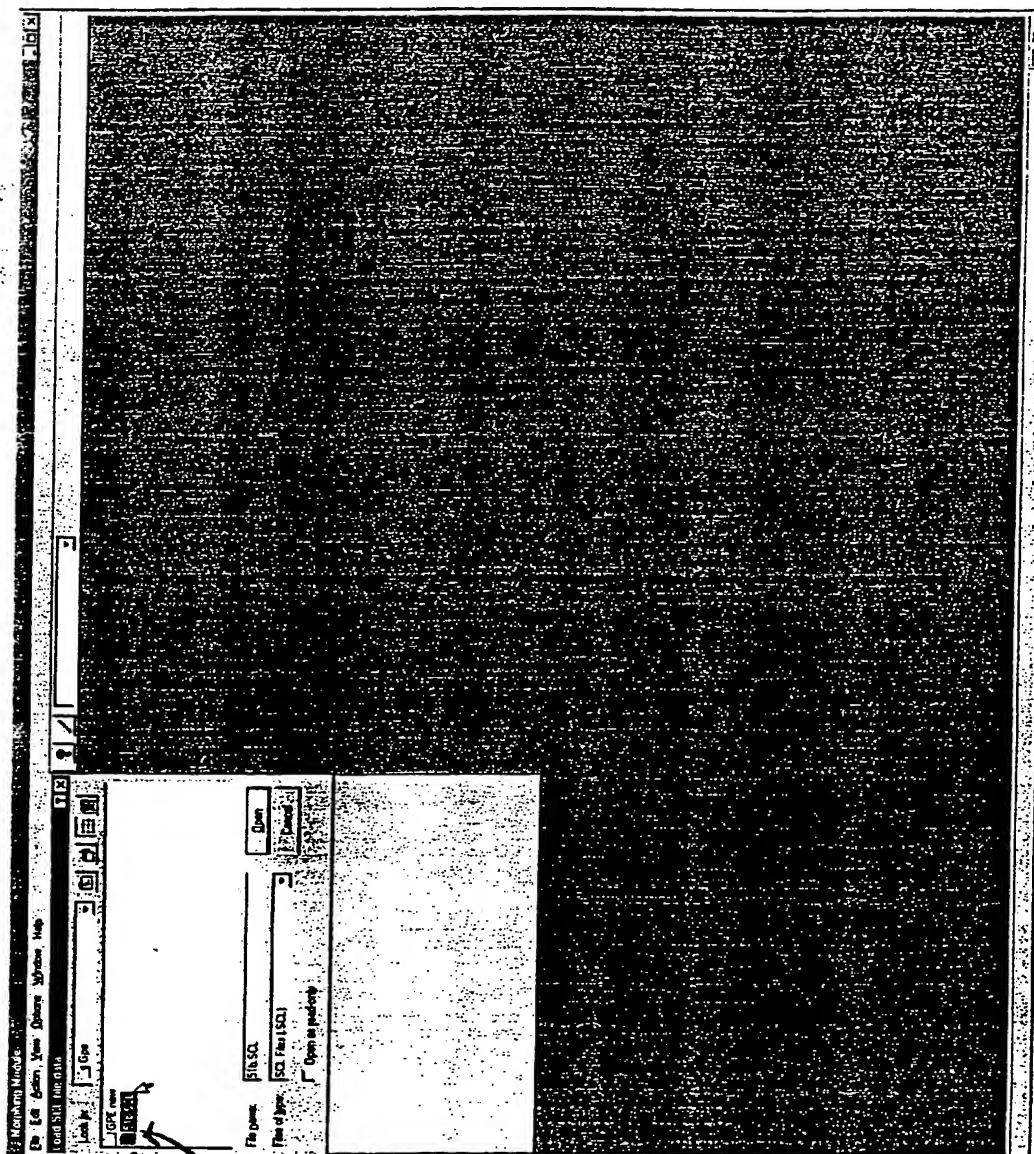
RIGHT MANDIBLE TRACE 2110

Figure 25

Use of SCL File

MORPHING INTERFACE 2600

PARTIALLY MORPHED STOCK MODEL 2610
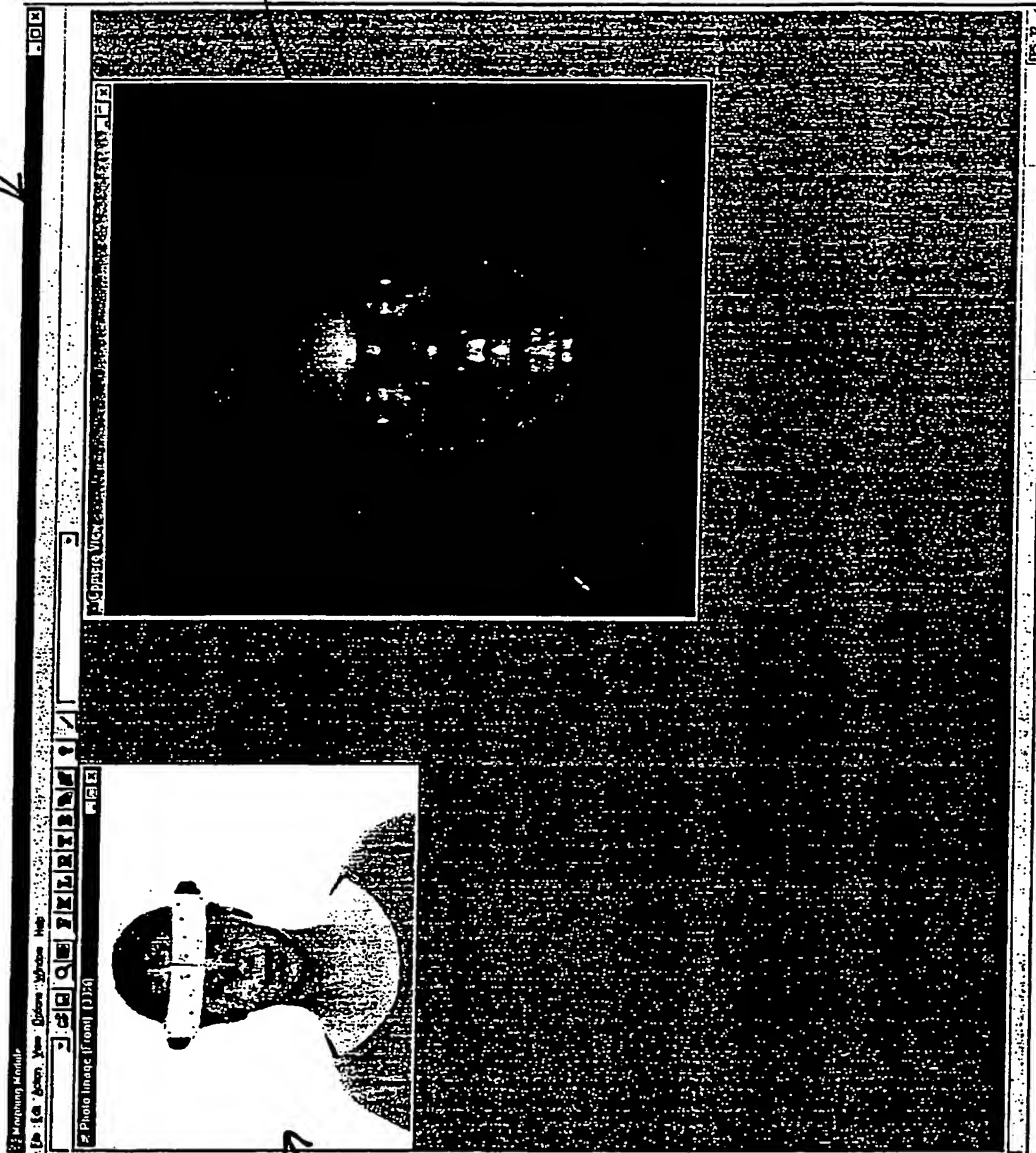
PATIENT IMAGE 750

FIGURE 26

Partial morph of stock model to patient specific

MORPHED +
TEXTURE
MAPPED
PATIENT
SPECIFIC
MODEL
2710
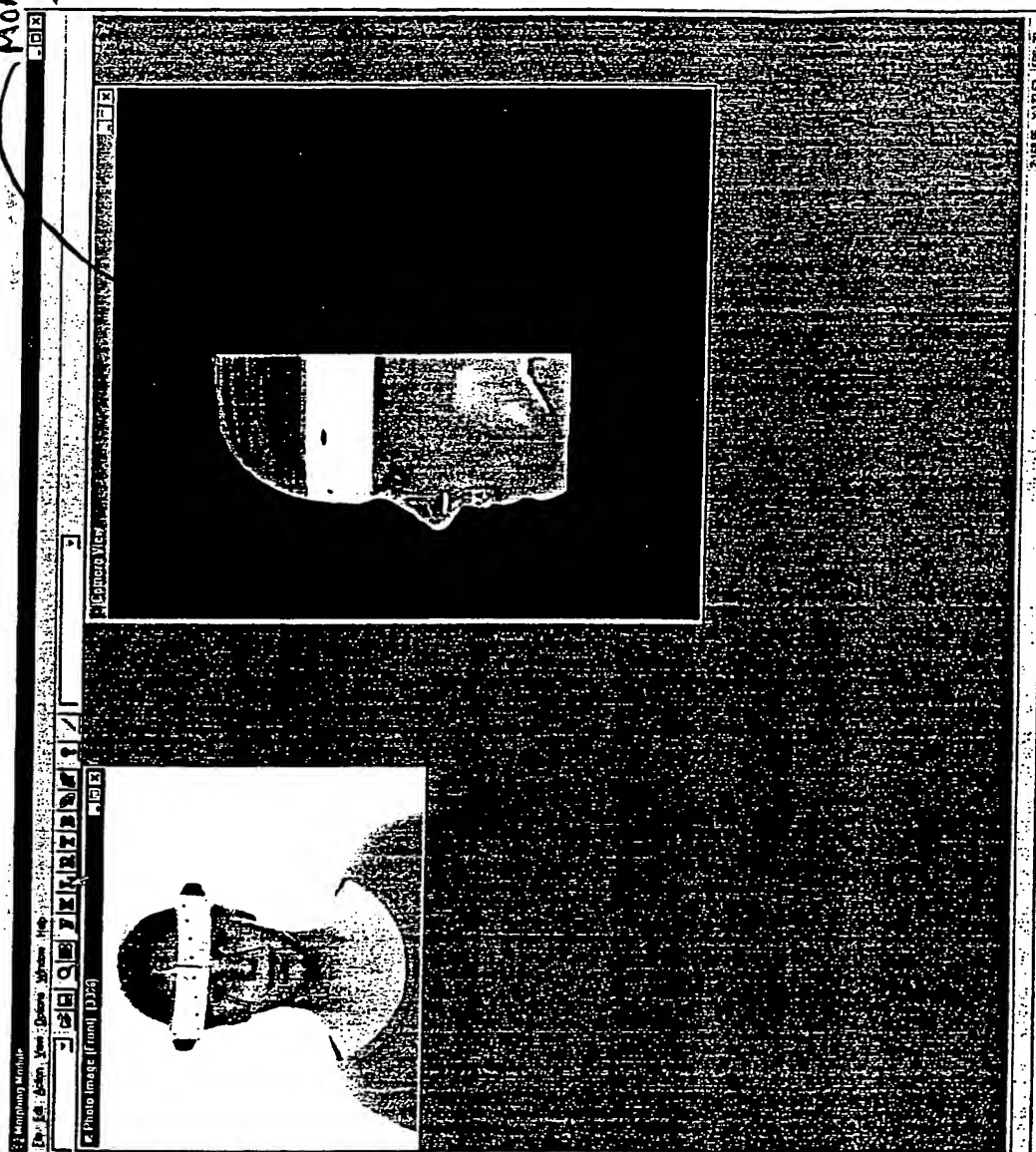
Figure 27

Photo texture on patient specific model side view
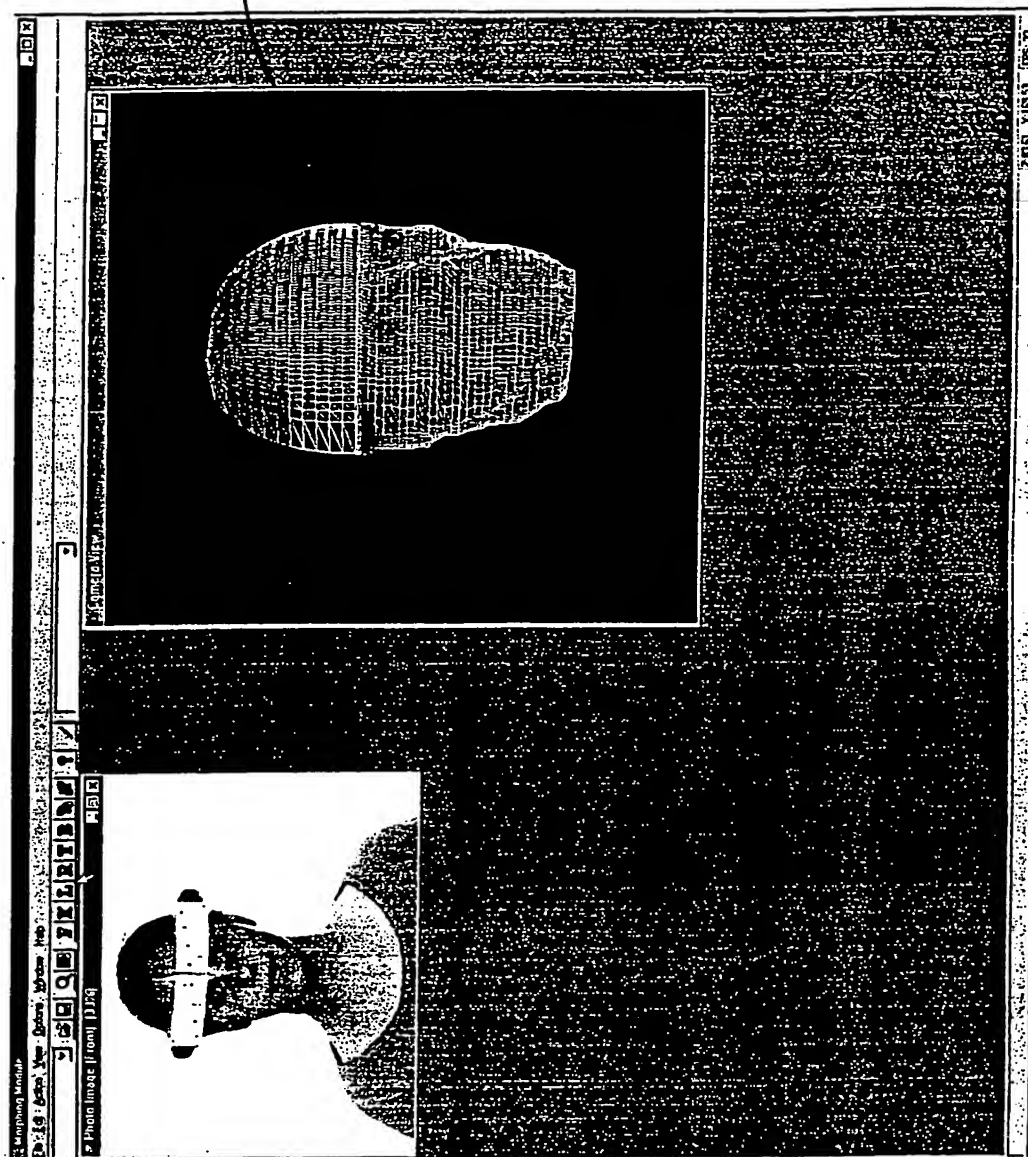
WIREFRAME
VIEW
2810

FIGURE 28

Wireframe model in morph module

Dot
Contour
VIEW
2910

Figure 29
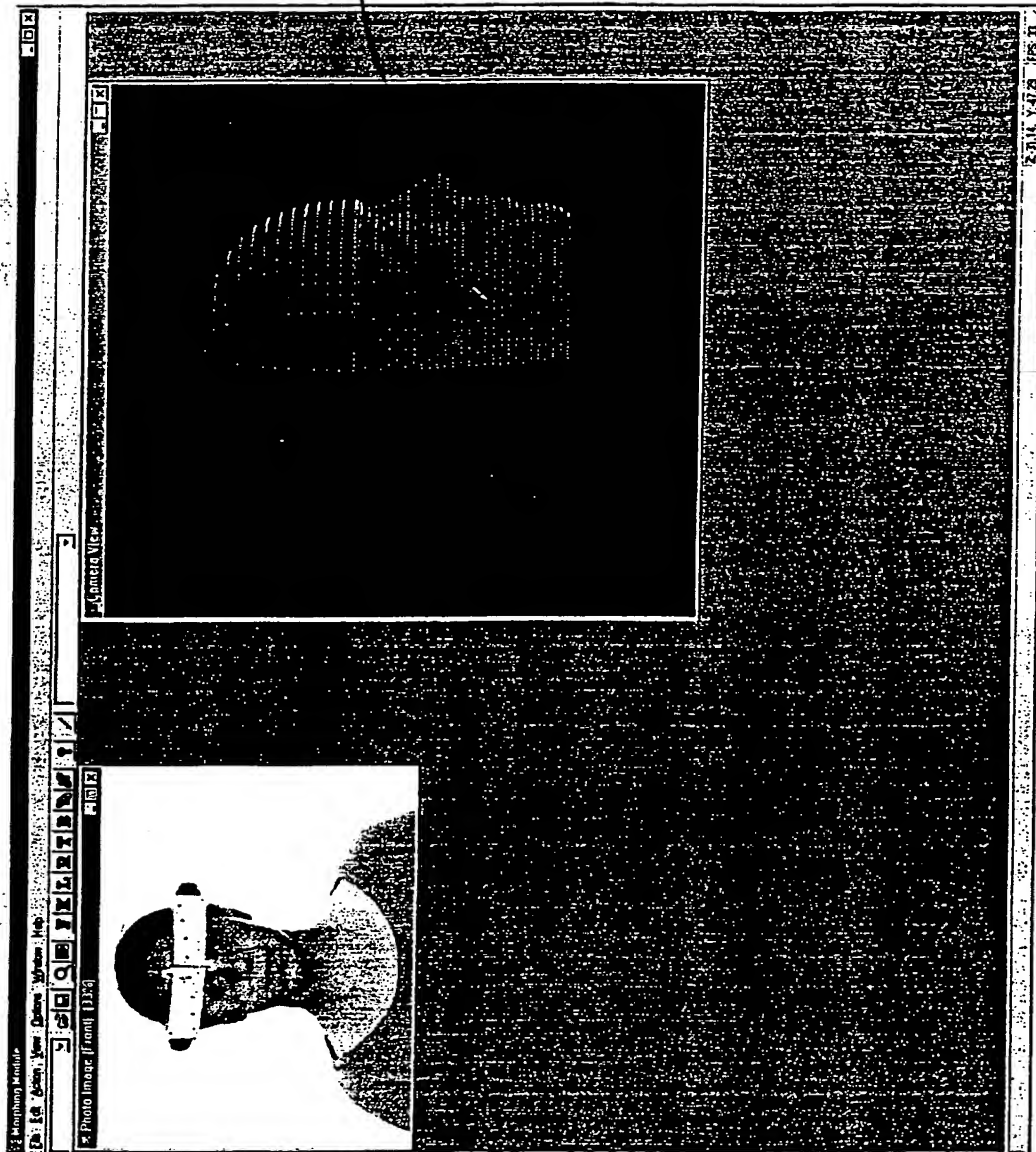
dot contour in morph module

CLINICIAN INTERFACE 3010
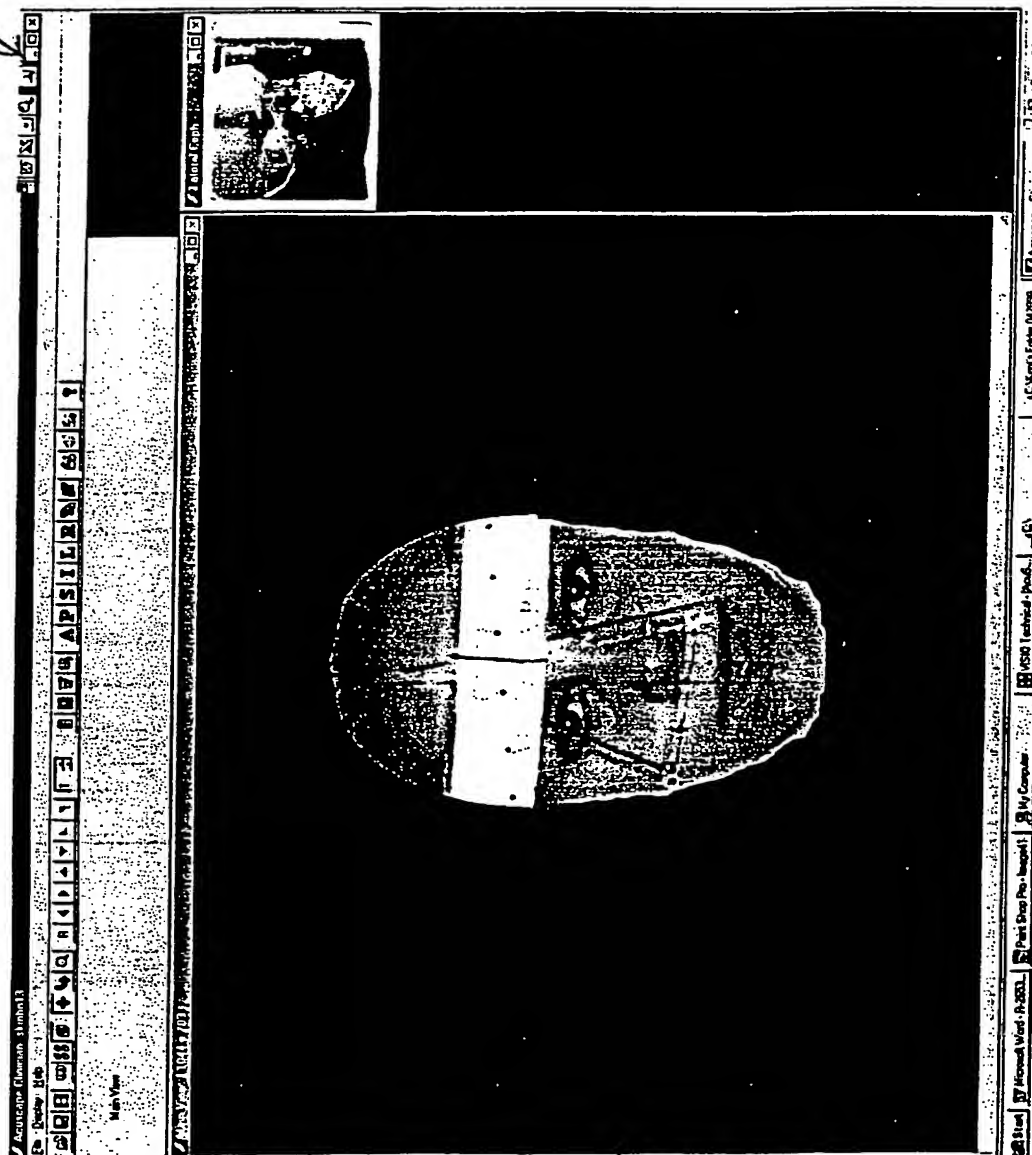
CLINICIAN TOOLBAR 3020

PATIENT SPECIFIC FLESH MODEL VIEW 3010

FIGURE 3Q

Clinician with intial model
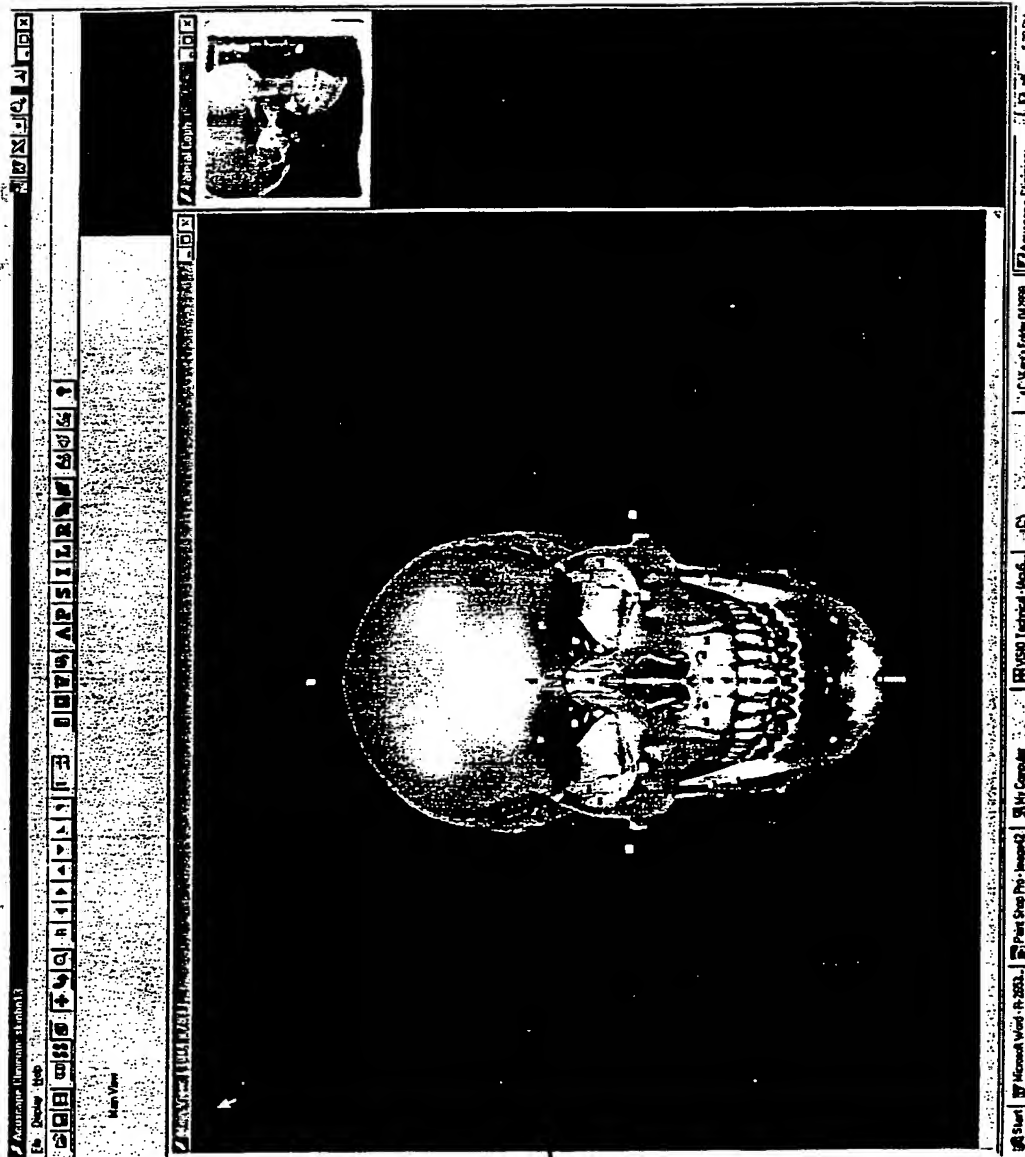
FIGURE 31

Skeleton with landmarks and control points

PATIENT
SPECIFIC
MODEL
SKULL
VIEW
31 210

Steiner Analysis with 2D + 3D images
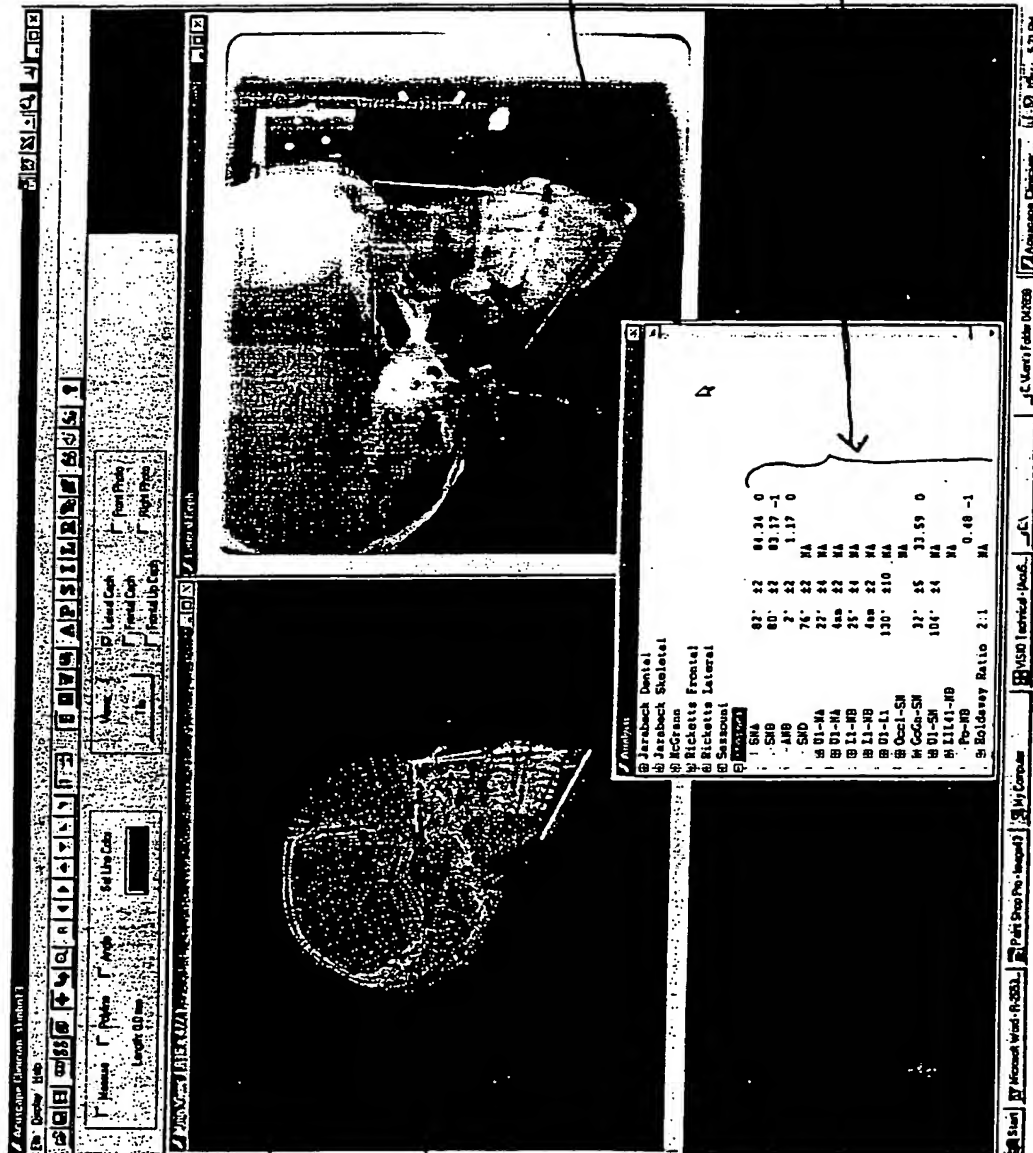
FIGURE 32

JAW
OBJECT
DOT DISPLAY
3310

ARCH
FORM
TEMPLATE.
3320
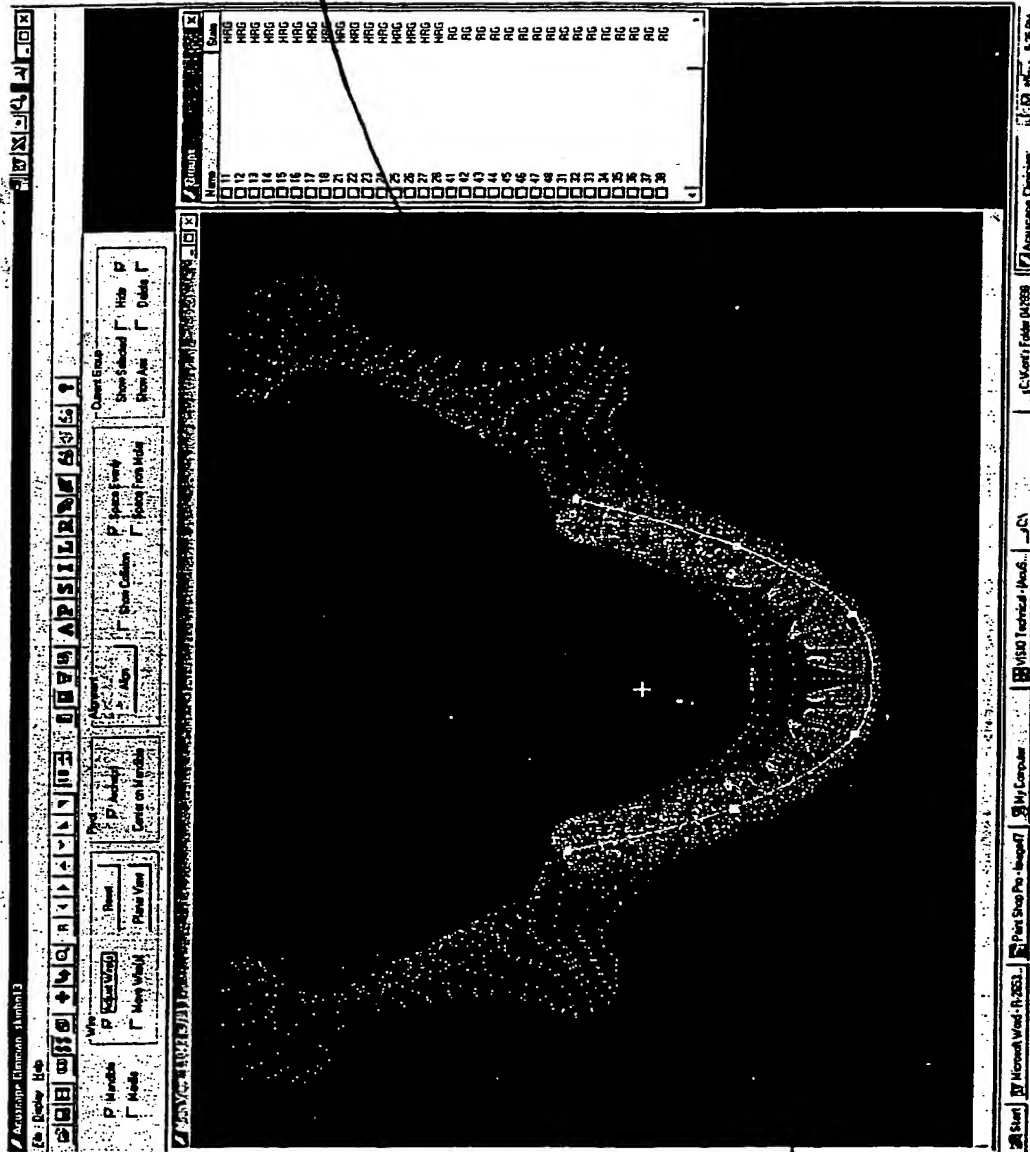
FIGURE 33

Top view of arch form template.
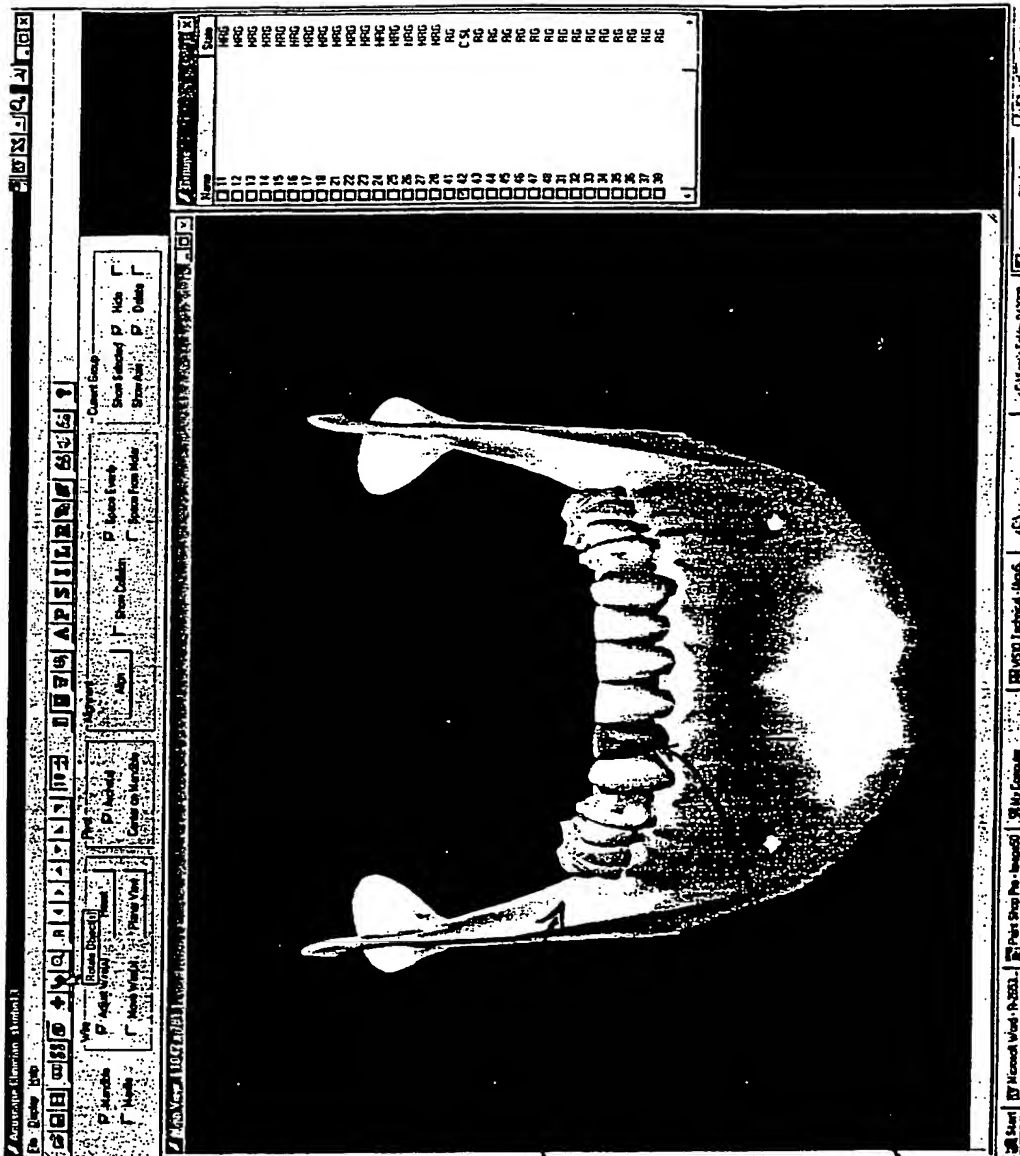
FIGURE 34

Selected tooth front image

JAW OBJECT SOLID DISPLAY 3410

TOOTH SELECTED DISPLAY 3420
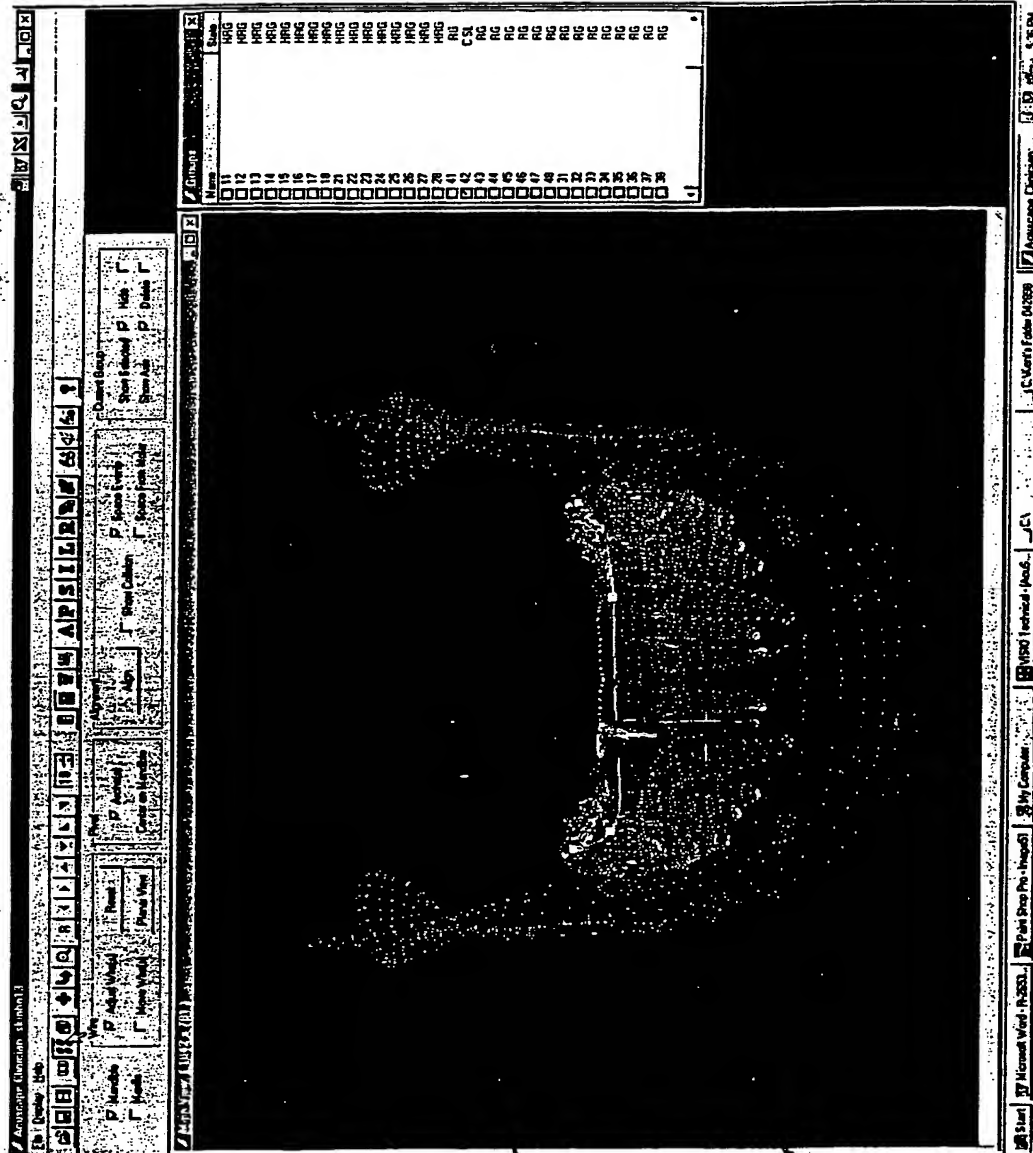
Tooth selected dot contour image

FIGURE 35
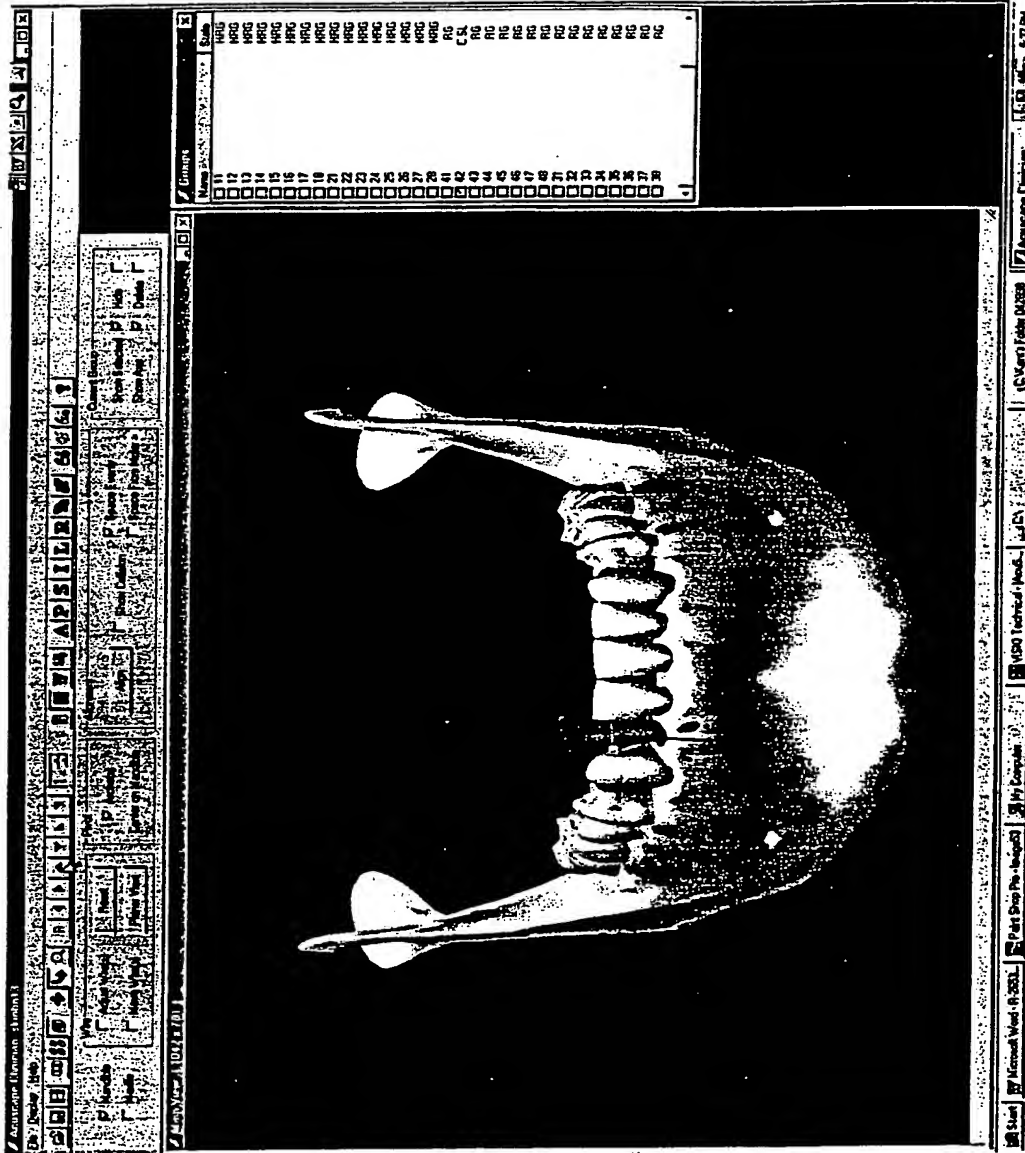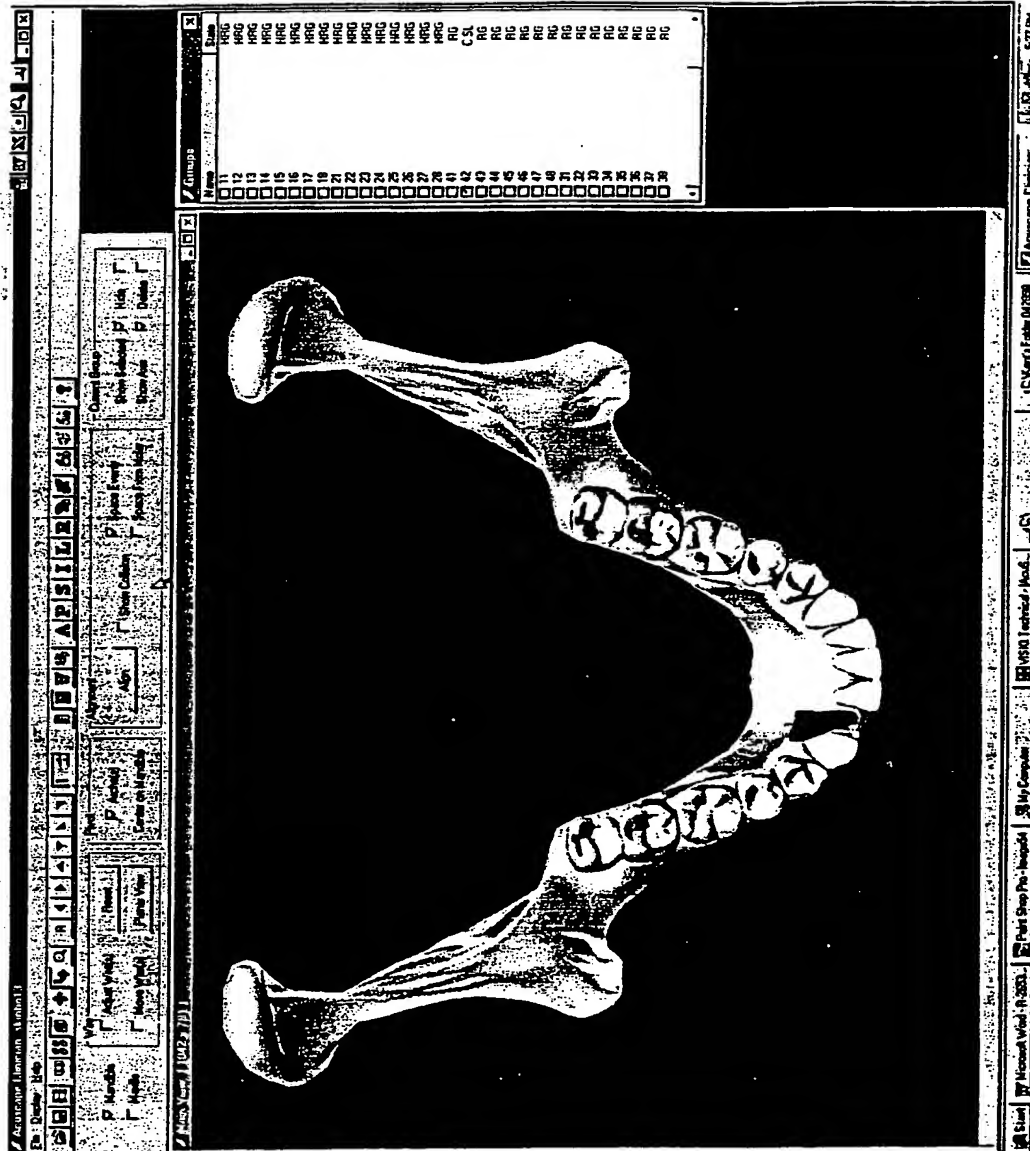
JAW OBJECT DOT DISPLAY 3510

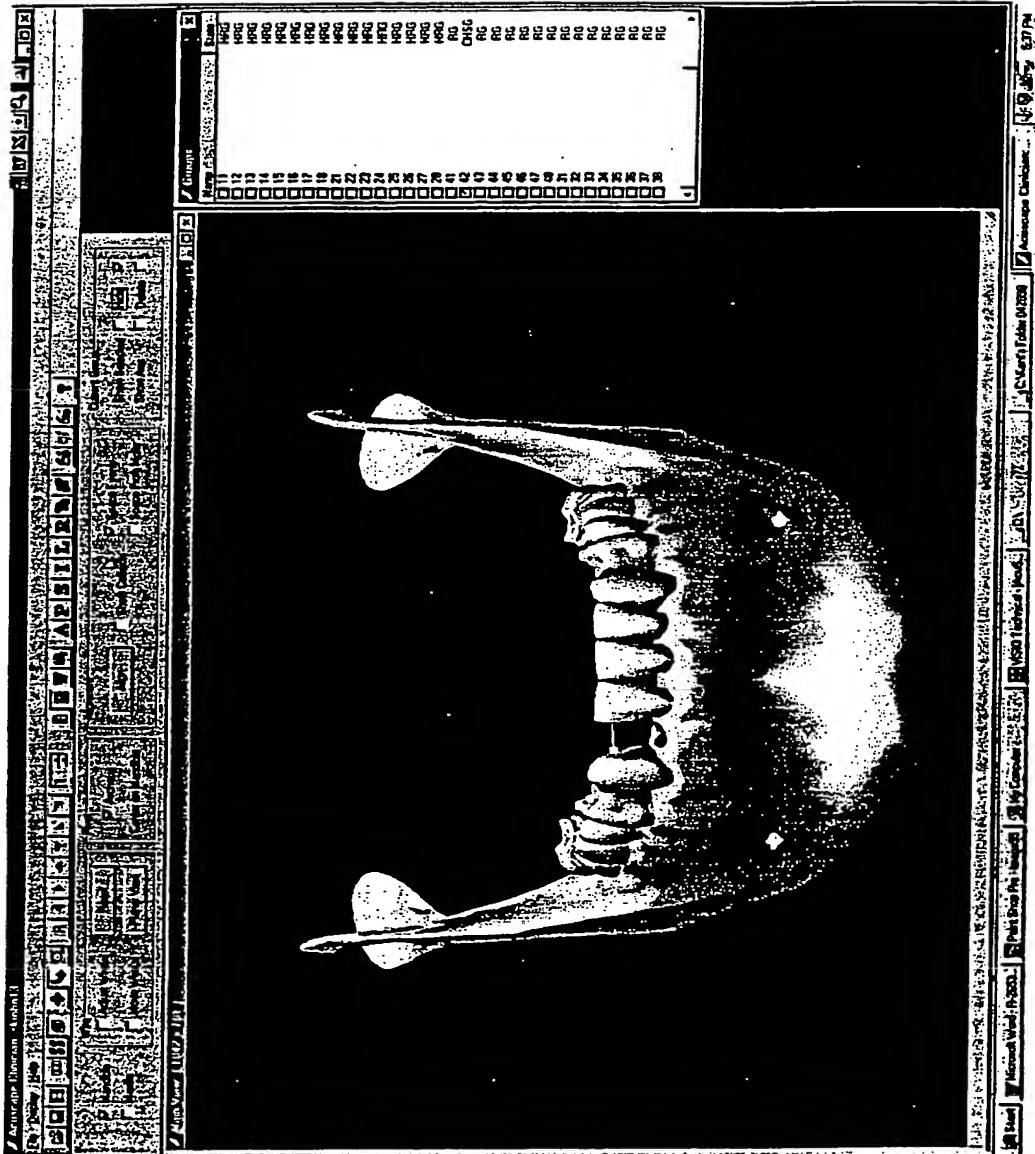SELECTED TOOTH DISPLAY 3420

Figure 36

Tilted Tooth Front View

FIGURE 37
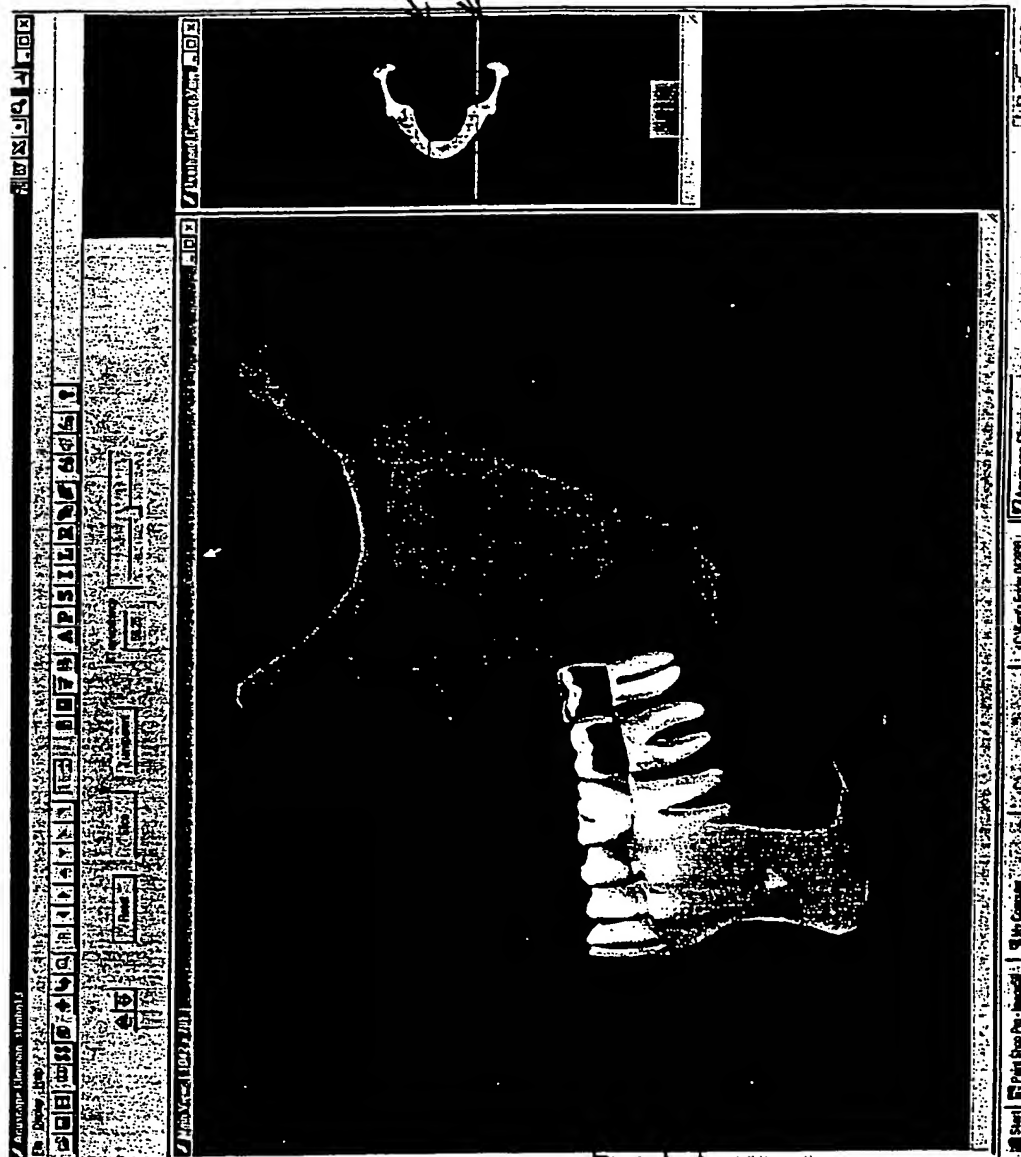
Tilted tooth top view

Figure 38

Extracted tooth object

JAW OBJECT DISPLAY 3920

SLICE PLANE 3910

JAW OBJECT SLICED DISPLAY 3930

Figure 39

Slice plane of Jaw

TRANSPARENT SLICE PLATE 4010

TRANSPARENT SLICE PLANE 4020

JAW OBJECT DISPLAY WITH TRANSPARENT SLICES 4030
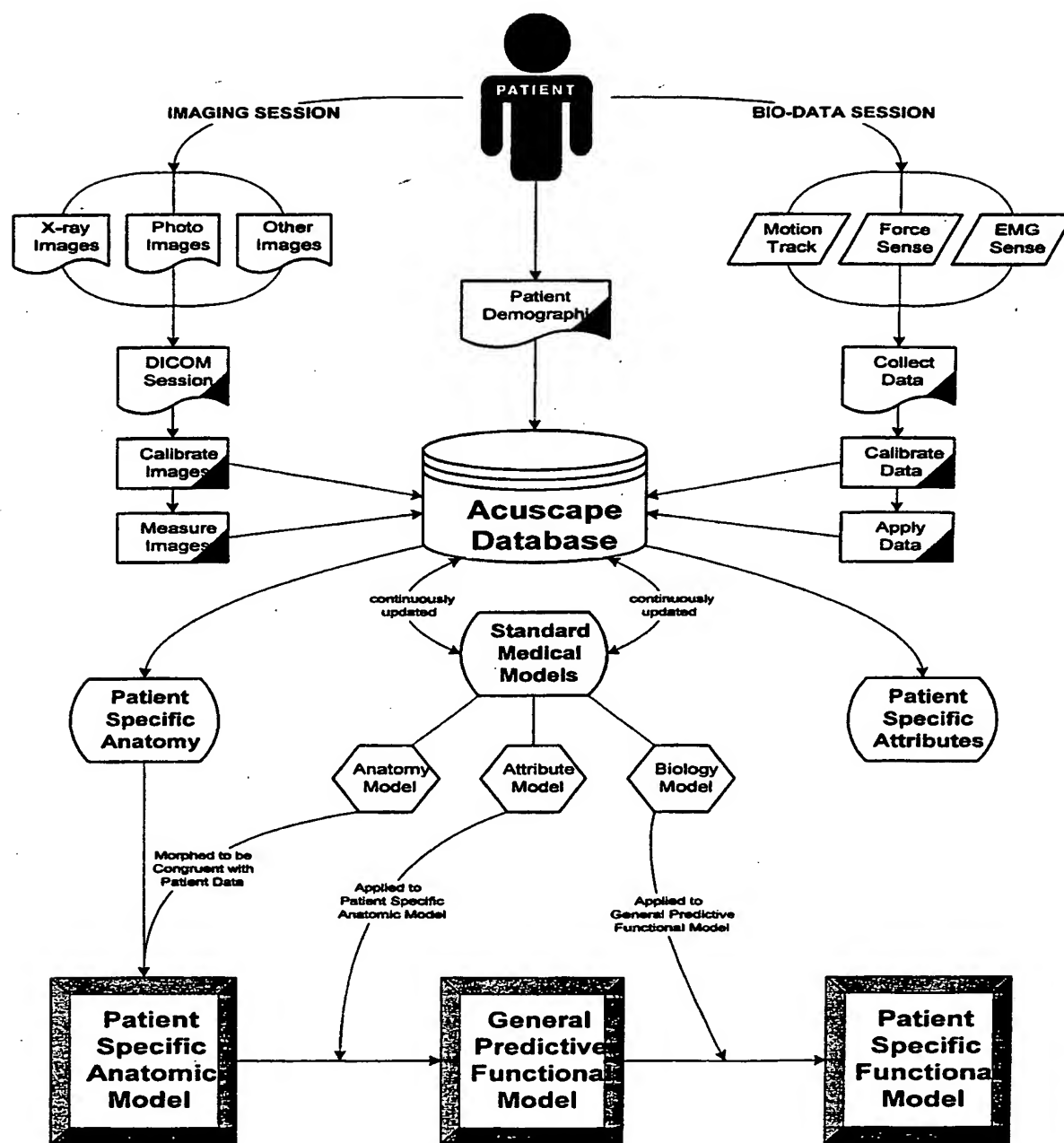
Transparent Jaw with slice planes

FIGURE 40

ISIONS:

FIGURE 41

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10566

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06T 15/00, 17/00; A61B 6/00, 6/14

US CL :345/425,427; 600/414

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/425,427; 600/414

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,945,914 A (ALLEN) 07 August 1990, see all figures, col. 2, lines 34-39.	21-23,27-28
X	US 5,005,578 A (GREER et al.) 09 April 1991, figures 2A-2B.	1-4
X	US 5,273,429 A (REKOW et al.) 28 December 1993, col. 2, lines 33-36; col. 3, lines 19-24, 39-42, 45-49, and 65-68; col. 4, lines 1-5.	9-13
---		------
Y		20

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 AUGUST 1999	**1 9 OCT 1999**

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	MARK POWELL *James P. Matthews*
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3900

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/10566

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X - Y	US 5,257,203 A (RILEY et al.) 26 October 1993, abstract, col. 2, lines 55-64; col. 3, lines 9-11col. 9, lines 50-55; col. 10, lines 5-10.	9-13 -- 20,26
X - Y	US 5,274,551 A (CORBY, Jr.) 28 December 1993, col. 3, lines 7-3.	9-13 -- 20
X - Y	US 5,278,756 A (LEMCHEN et al.) 11 January 1994, col. 1, lines 21-27 and 32-39; col. 2, lines 29-32 and 64-69; col. 3, lines 1-2, 22-25, 30-35, 40-46, and 51-52.	1-4,14-16, 18-19, 21-23, 27-28 ---------- 20,23-24
Y	US 5,356,294 A (ODOMO) 18 October 1994 col. 1, lines 50-60 and col. 3, lines 55-61.	9-13, 20
X - Y	US 5,737,506 A (MCKENNA et al.) 07 April 1998, col. 2, lines 33-35 and 66-67; col. 3, lines 1-5.	7-8, 9-13, 21-22, 26, 28 ---------- 20
X	US 5,740,802 A (NAFIS et al.) 21 April 1998 col. 2, lines 44-46; col. 3, lines 50-52.	1-5, 7-8, 9-20, 24-25,26-28
Y	US 5608774 A (POLICHAR et al.) 04 March 1997 col. 15, lines 65-67 and col. 16, lines 1-25.	17,22
X - Y	WO 97/23164 (NAVAN et al.) 03 July 1997, page 2, lines 18-35,page 3, lines 1-24 and page 7, lines 25-30, see all figures.	1-6, 4-16, 18-19,21-22, 23 ---------- 17, 20
X	WO 92/06645 (BUCHOLZ, RICHARD) 30 April 1992, abstract, all figures.	1-4
X	WO 97/03601 (CHEN et al.) 06 February 1997, abstract, all figures.	7-8, 9-13, 20-22, 28-29
X,E	US 5,889,524 A (SHEEHAN et al.) 30 March 1999, abstract, all figures.	9-16, 18-28

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INTERNATIONAL SEARCH REPORT

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SEERAM, Edward. 3-D Imaging: Basic Concepts for Radiological Technologists Radiologic Technology, December 1997, Vol. 69, No. 2, pages 127-144.	1-28
A	ROBB, R.A. et al. Patient-specific Anatomic Madels from Three Dimensional Medical Image Data for Clinical Applications in Surgery and Endoscopy, Journal of Digital Imaging, August 1997, Vol. 10, No. 3, pages 31-35, especially page 31.	1-28
A	MACIUNAS, Robert J. The Application Accuracy of Stereotactic Frames. Neurosurgery, October 1994, Vol. 35, No. 4, pages 682-695.	1-28
A	SCHELLHAS, K. P. et al. Three-dimensional Computed Tomography in Maxillofacial Surgical Planning. Archives of Family Medecine: Otolaryngol Head Neck Surgury, March 1993, Vo. 114, April 1988, pages 438-442.	1-28
A	DECLERCK, J. et al. Automatic Registration and Alignment on a Template of Cardiac Stress and Rest SPECT Images. Proc. of the Mathematical Methods in Biomedical Image Analysis Workshop. 22 June 1996, pages 212-221.	1-28
A	SELLBERG, M.S. et al. Virtual Human: a Computer Graphics Model for Biomechanical Simulations and Computer-aided Instruction. Proc. of the 16th Conf. of the IEEE on Engineering Advances: New Opportunities for Biomedical Engineers, 6 November 1994, pages 329-330.	1-28

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,099,846 A (HARDY) 31 March 1999, col. 6, lines 23-27, 43, 65-68; col. 12, lines 33-36 and 45-50.	21-23, 26-28
X	US 5,490,221 A (RANSFORD et al.) 06 February 1996, abstract, col. 3, lines 59-64; col. 4, lines 49-61	26
X - Y	US 5,742,291 A (PALM) 21 April 1998, abstract, col. 2, lines 9-11, 46-49, 57-61; col. 3, lines 4-6; column 4, lines 64-67; column 5, line 22 and 61-66; column 6, lines 13-17, 39-41, and 56-59, column 7, lines 45-47; column 9, line 61.	7-23, 26-28 ----- 24-25
Y	JP 8335278 A (GOTO) 17 December 1996, abstract.	24-25
Y,&	US 5,920,660 A (GOTO) 6 July 1999, abstract.	24-25
A,&	US 5,798,924 A (EUFINGER et al.) 25 August 1998.	1-28
X;P	US 5,776,050 A (CHEN et al.) 07 July 1998, abstract, all figures.	9-13
X,P	US 5,926,568 A (CHANEY et al.) 20 July 1999, abstract, column 2, lines 30-35 and column 3, lines 39-41.	9-13
X	WO 96/10949 (CHEN et al.) 18 April 1996, pages 1-13, all figures.	21-22, 26-28
A,&	US 5,769,861 A (VILSMEIER) 23 June 1998	1-28
Y,P	US 5,910,107 (ILIFF) 08 June 1999.	26

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B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS, WPI, DIALOG, MEDLINE, NTIS, INSPEC, COMPENDEX, JICST, New Eng. Jrl. Med., ELSEVIER, PASCAL, HEALTHSTAR, AMA
search terms: patient specific, 3d, model, calibrate, anatomy, morph, sculpt

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group 1, claim(s)1-6, drawn to details of a calibration apparatus including calibration targets.
Group 2, claim(s) 7-13, and 26 drawn to software for three dimensional modeling of a patents anatomy including patient specific information.
Group 3, claim(s) 14-24, & 27-28 drawn to details of software for calibrating an a three dimensional patent imager, or generically, calibrating a three-dimensional imager.

The inventions listed as Groups 1-3 do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the details of the calibration apparatus is a separate and distince technical feature. The software for imaging a patient in 3-D employing customization features is a separate and distinct technical feature. The mathematical steps employed to calibrate the imager is a separate and distinct technical feature.

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